Windfalls for All? International Elasticities and Dutch Disease in a Commodity Exporting Economy *

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Abstract: This paper analyzes the effect of commodity price fluctuations on both overall and sectoral outcomes in a commodity exporting economy. Using Chilean and international copper market data, I find positive copper price changes stemming from copper-specific demand shocks generate a broad GDP expansion with no visible decline in the exports of any sector, including manufacturing. These results provide evidence against the Dutch disease hypothesis involving the crowding out effect of commodity price increases on the manufacturing sector. I then estimate key structural parameters of a small open economy business-cycle model with 6 sectors by matching my empirical impulse responses and find that a low degree of substitution between domestic and foreign goods explains the positive sectoral effect of a commodity price shock. Finally, I evaluate how tariffs on imports shape the effect of commodity price shocks and find low tariffs make the small open economy less sensitive to commodity price shocks when the elasticity of substitution between domestic goods and imports is small.
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Many emerging economies depend on commodities whose prices are volatile. High prices for these commodities naturally help those sectors related to the production of the commodities, but the economic benefits on other sectors are ambiguous. For example, an increase in the commodity price will generally lead to an appreciation of the exchange rate (Chen and Rogoff 2003, Cashin et al. 2004), which makes foreign goods cheaper and domestic exports more expensive. Non-commodity sectors may therefore be hurt by the currency change. Furthermore, if the commodity producing sector expands, it will demand more inputs, which will raise the costs of production in other sectors. Jointly, this crowding out effect of non-commodity producing sectors, and especially the exporting sectors like manufacturing, is known as the Dutch disease.

However, the effect of a rise in commodity prices on other sectors does not have to be negative. When commodities represent a high proportion of GDP and exports, increases in commodity prices also expand revenues of the commodity sector, increasing aggregate income in the economy. This means the demand for goods and services provided by other sectors will be greater, which will tend to increase the economic activity of those sectors. The net effect of commodity price changes on a commodity exporting economy is, therefore, *ex-ante* ambiguous.

In this paper, I tackle this question by studying the empirical effects of copper price shocks on both the overall economy and different sectors in Chile, a copper exporting economy.[1] Then, I analyze with an estimated small open economy model how the different forces shape the overall and sectoral effects of a commodity price shock. I find that the elasticities of substitution between domestic and foreign goods play a key role in explaining why substitution effects associated with changes in the exchange rate are overwhelmed by positive demand side effects of the shock. This paper also evaluates how trade policy related to tariffs on imported goods shape the effect of commodity price shocks in the small open economy model.

Because commodity prices are endogenous to global conditions as well as conditions in commodity exporting economies, I start by identifying commodity-specific demand shocks from an empirical model of the international copper market. These shocks serve as a powerful instrument for copper prices that enable to estimate the effects of exogenous copper price shocks on the Chilean economy.[2]

My main empirical result is that an increase in copper prices leads to a broad-based expansion in economic activity across all sectors of the Chilean economy. Despite the appreciation of the real

[1]Copper represents between 30% to 60% of total Chilean exports and around 12 % of total GDP.

[2]Chile is the biggest exporter of copper in the World, selling between 25% and 40% of refined copper internationally traded. Additionally, World economic activity can affect copper prices and non-copper exports directly. An empirical identification strategy to deal with them is to use instrumental variables to isolate copper price changes from shocks coming from the Chilean economy and World economic activity.

exchange rate, sectoral exports do not fall. Manufacturing exports from sectors related to copper extraction expand while exports from other manufacturing sectors do not change significantly. This is direct evidence against the Dutch disease in Chile related to a potential crowding out effect of commodity price increases on the manufacturing sector.

I then develop a small open economy (SOE) model of the Chilean economy with 6 productive sectors. Three of them, tradable non-commodity, commodity, and non-tradable, use capital and hours worked by households in order to produce goods. The other three sectors use domestic products and imported goods as inputs. I estimate the structural parameters of the SOE model using impulse response matching (Christiano, et al. 2005) with my empirical estimates from the Chilean economy in order to discipline the model. Matching the impulse responses of the Chilean economy to copper price shocks allows me to quantify the income effects associated with changes in aggregate earnings and the substitution effect related to the movement of the exchange rate.

The analysis of the small open economy model indicates that exports and output of tradable sectors fall when the elasticity of substitution between domestic goods and imports, and/or the price elasticity of exports increases. These elasticities govern the sensitivity of domestic products to changes in the real exchange rate, determining if a small open economy experiences the Dutch disease or not. Additionally, counterfactual exercises reveal large income effects on labor supply generate a small reaction of hours worked and output.

Trade policy also affects the sensitivity of the SOE model to commodity price shocks, in which high tariffs on imports amplify the positive effect of commodity price shocks on aggregates when the degree of substitution between domestic and foreign goods is low, because tariffs make domestic goods relatively cheaper than imports, increasing the domestic demand for tradable non-commodity goods. When import tariffs are high, the amplified increase in demand for domestic goods associated with a commodity price shock is covered with an expansion in production, generating a large increase in household incomes and the demand for goods and services, producing a broad expansion of the economy.

Related literature: This paper contribute on the extended literature about the sectoral effects of commodity prices changes by analyzing how the demand sensitivity for national tradable goods to changes in the real exchange rate associated with commodity price variations determine if the manufacturing sector shrinks or not and the effect on non-commodity exports, which Corden and Neary (1982) starts proposing the Dutch disease hypothesis about the relation between commodity booms and contraction of manufacturing sectors, a hypothesis studied empirically by Charnavoki and Dolado (2014), Allcott and Keniston (2018), and Benguria, Saffie, and Urzua (2023). Furthermore, this work shows that the degree of substitution between domestic and foreign goods, as well as the income effect on labor supply and trade policy related to tariff on imports shape the effects of commodity price movements on aggregate fluctuations in exporting economies, building on the literature about business cycles and international price changes (Shousha, 2016, Fernández, González, and Rodríguez, 2018, Fernández, Schmitt-Grohé and Uribe, 2017, Kohn, Leibovici, and Tretvoll, 2021). This work also contributes analyzing the role of elasticity of substitution shaping effects of international price shocks across sectors through changes in the real exchange rate, in which Backus, Kehoe, and Kydland (1994) and Heathcote and Perri (2002) describe the relationship between the elasticity and business cycles features, and Boehm, Flaeen, and Pandalai-Nayar (2019), Barrot and Sauvagnat (2016), Atalay (2017); and Peter and Ruane (2023) extend it analyzing the importance of elasticity of substitution on the effect of exogenous shocks across sectors.

Finally, I study how the effect of international market shocks changes depending on the level of tariffs on imports, which provide a new angle of study in the extensive literature of the effect of trade policy.[3]

This paper is structured as follows, Section 1 lays out the world copper market and the estimation of demand and supply shocks. Section 2 presents the effects of copper price change in Chile using IV local projection. Section 3 describes the small open economy (SOE) model. Then Section 4 presents the estimation of the structural parameters of the SOE model. Section 5 compares the theoretical effects of commodity price shocks when elasticities of substitution and the income effect parameter on labor supply change. Section 6 analyzes how trade policy shapes the impact of commodity price shocks. Lastly, Section 7 presents conclusions.

I The world refined copper market

Chile is the biggest exporter of refined copper in the World, selling between 25% and 40% of total refined copper internationally traded, then shocks coming from the Chilean economy can affect refined copper prices through changes in Chilean copper production. Changes in global economic activity also affect copper prices and exports of non-copper sectors as well,[4] being unable to argue changes in other sectors are related to shocks in the copper market or changes coming from global economic activity.

For validity and interpretative reasons, I use foreign shocks specific to the international copper market as a source of variation in real copper prices. I estimate these shocks using a Structural Vector Autoregressive (SVAR) model based on Kilian (2009). I use the quarterly average of copper-

[3] Goldberg and Pavcnik (2016) and Caliendo and Parro (2022) provide an updated review of the literature on trade policy.

[4] E.g. an expansion of the Chinese economy increases its imports of refined copper and Chilean wines.

specific demand shocks recovered from SVAR estimation of the World copper refined market as instruments to isolate price changes coming exclusively from the international copper market.

I.A: The refined copper industry

Industries use refined copper as input to produce electrical wires, industrial machinery, and building material for roofing and plumbing.[5] Refined copper supply comes from two sources, primary production through the processing of copper ore extracted from mines, and secondary production coming from recycling old scraps. Primary production represents the main source of refined copper production.[6] This commodity is traded internationally between producers and customers using spot prices from world metal markets such as the London Market Exchange (LME) and Commodity Exchange Inc. (COMEX) as price references.

China has become the largest user and importer of refined copper in the World during the last 25 years, consuming around 53% and importing around 41% of total refined copper internationally traded between 2016 and 2020.

Chile is the biggest exporter of refined copper, selling between 25% and 40% of refined copper internationally traded between 1996 to 2020. This large participation in global markets makes Chilean supply shocks important to the international refined copper market. More than 15 companies extract mines in Chile, and 7 of them produce around 80% of Chilean copper.[7]

A feature about copper and refined copper production in Chile is less variable than the refined copper price, as Figure 1 indicates. The next sections show this is evidence of low sensitivity of production to copper demand shocks.

I.B: An empirical model of the World refined copper market

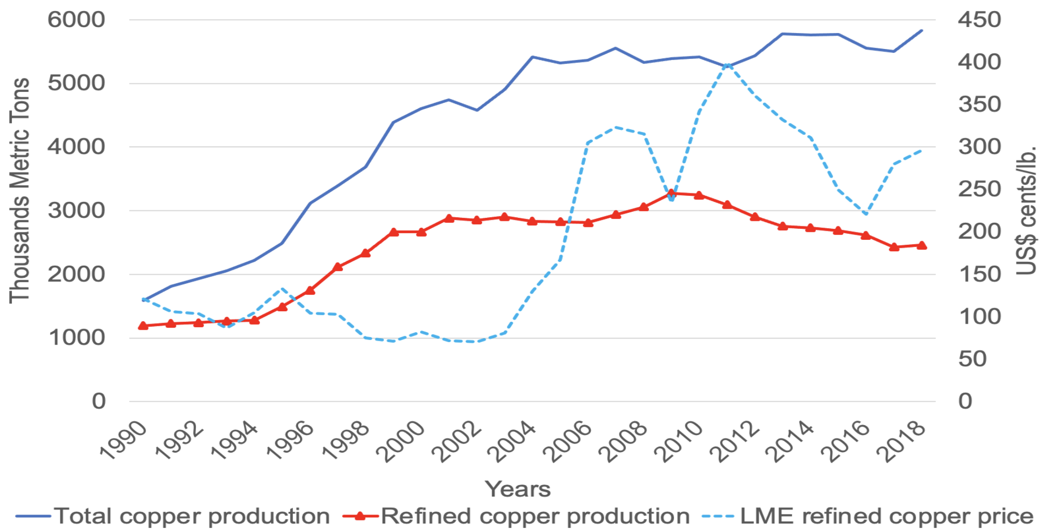
Kilian (2009) proposes a method to recover demand and supply shocks from industrial commodities markets, such as copper, using a Structural Vector Autoregressive (SVAR) model. This model estimates demand shocks related to changes in global real economic activity and those specific shocks related to refined copper demand. I can also separate copper supply shocks coming from Chile and the rest of the world separately.

[5]Copper is a metal characterized by malleability and ductility with high thermal and electrical conductivity.

[6]Aguirregabiria and Luengo (2016) shows that secondary production grew at a much slower pace than primary production between 1990 and 2008, representing around 20% of total refined copper supply by 2008. The high cost of recycling explains this feature.

[7]Appendix I presents descriptive statistics of the world copper market and the Chilean copper industry.

Figure 1: Total copper and refined copper production in Chile



Note: The figure shows the total production of copper and refined copper in thousands of metric tons in Chile. Total copper production is the sum of non refined copper concentrate with 20 % to 50 % of pure copper and copper refined with 99.9 % pure copper using the SX-EW method. It also indicates the annual average reference price of refined copper grade A traded in the London Metal Exchange (LME) market. Source: Chilean Commission of Copper (Cochilco)

I use monthly data for the estimation. The variables of the model are the monthly percentage variation of the Chilean and World refined copper production, a global economic activity index,[8] and a log of the real price of copper. The SVAR model estimated is:

$$A_0 z_t = \alpha + \sum_{i=1}^{24} A_i z_{t-i} + \varepsilon_t \tag{1}$$

z_t is the group of variables used in the model. The expression ε_t is the group of serially and mutually uncorrelated structural innovations. Assuming recursive identification, the reduced form error e_t from the associated reduced form VAR can be decomposed in terms of the group of shocks as $e_t = A_0^{-1}\varepsilon_t$:

[8] I computed global economic activity as the first common factor from a panel of commodity prices defined by Alquist, Bhattarai, and Coibion (2019). The group of commodities excludes those commodities vertically integrated and closely associated, as well as precious metal prices that behaved as financial assets. The comovement of this panel of commodities prices is related to changes in global economic activity. Kilian and Zhou (2018) discuss and compare in detail different measures of global demand for commodities.

$$e_t \equiv \begin{pmatrix} e_t^{\Delta Production\,Chile} \\ e_t^{\Delta Production\,World} \\ e_t^{Index\,Econ.\,Activity} \\ e_t^{Real\,Price\,Copper} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{Chile\,copper\,supply\,shock} \\ \varepsilon_t^{Rest\,of\,the\,world\,copper\,supply\,shock} \\ \varepsilon_t^{Aggregate\,demand\,shock} \\ \varepsilon_t^{Copper-specific\,demand\,shock} \end{pmatrix}$$

I assume that the monthly supply curve is vertical, which means monthly production doesn't change when there is a demand shock in the same month, reacting with at least a delay of a month. A shift in the demand fueled by shocks will change the real price of copper immediately, as well as unanticipated copper supply shocks. Similarly, supply shocks from the rest of the world do not affect Chilean copper production in the same month. The recursive identification assumption relies on primary production that depends on the availability of mines as a main source to produce refined copper. The expansion of existing mines takes at least one year and the development of new mines of copper requires between 2 to 5 years on average, plus the exploration process takes between 1 and 15 years.[9] Copper mining companies adjust their production in the extensive margin, through opening and reopening of mines. The opening of mines depends on firms' expectations about future copper prices and environmental regulations that allow companies to extract copper deposits.[10]

Aggregate demand shock explains variations in the index of economic activity that are not explained by copper supply shocks. This model imposes an exclusion restriction in which copper-specific demand shocks may affect economic activity only after a delay of one month. Additionally, unexpected changes in the real price of refined copper that are not explained by supply shocks and aggregate demand innovations are related to copper-specific demand shocks.[11]

I estimate the SVAR model of the world refined copper market with monthly refined copper production data from Bloomberg,[12] the Chilean Copper Commission (COCHILCO) computes the real price of copper, which is the monthly average price reference per pound of refined copper grade A traded in the London Metal Exchange, deflated by the U.S. producer price index. I use the International Monetary Fund primary commodity prices dataset to estimate the first common factor as the index of global economic activity. The sample period is from January 1995 to August 2018.[13]

[9]For more information see U.S congress, Office of technology assessment (1988).

[10]Obtaining regulatory permits to open a new mine takes on average more than 6 years in Chile.

[11]Kilian (2009) defines this commodity-specific demand shock as fluctuations in the precautionary demand, driven by uncertainty.

[12]This time series is estimated by the World Bureau of Metal Statistics.

[13]The sample period is determined by the availability on data of the monthly refined copper production.

I.C: The copper-specific demand shocks[14]

From the group of copper market shocks computed from SVAR, only other countries' supply shocks and copper-specific demand shocks can be used to analyze the effect of copper price shocks on other sectors because Chilean copper supply shocks are not a valid source of exogenous shocks to the Chilean economy.[15] Additionally, changes in World economic activity affect the copper sector and other sectors directly through variations in demand for exported goods.

Figure 2 illustrates the impulse response functions of real copper price, Chilean and World copper production to one standard deviation of a copper-specific demand shock from the SVAR. This demand shock generates a persistent expansion of real copper prices that last more than 4 years after the innovation.

Additionally, Chilean production decreases slightly to a copper-specific demand shock, while world production rises moderately. This indicates that foreign producers cover increases in demand, and copper supply is inelastic. The contraction of refined copper production is related to the decision of copper companies to change the composition of copper production between refined and unrefined copper.[16]

Figure 23 in Appendix II shows the impulse response function to a supply shock from other producers besides Chile. Despite other producers' supply shocks generating a significant and persistent change in the real price of copper, it is not a relevant instrument for real copper prices.[17]

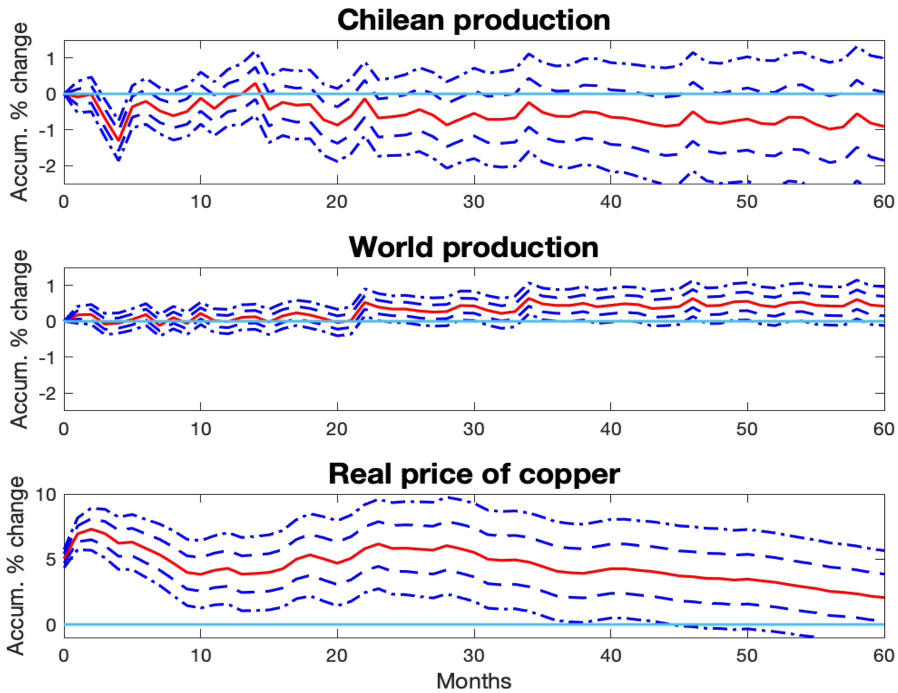
[14]Appendix II shows the historical evolution of shocks and the impulse response function for demand and supply shocks.

[15]Chile is a small commodity exporting economy that exports around 96% of refined copper production. Based on this, demand shocks recovered from the SVAR model of the world refined copper market are exogenous to the Chilean economic activity, and they accomplish with the exclusion restriction assumption for instrumental variables.

[16]Figure 24 in Appendix II shows the impulse response function of the international market for refined and unrefined copper, which Chilean copper production does not change to copper-specific demand shock, which is related to the decision of copper companies to increase exports of unrefined copper. Also in this model, the reaction of real refined copper price does not differ with respect to the model of the refined copper market shown in Figure 2.

[17]First stage F statistic of the IV local projection using other producers' supply shock as an instrument is 0.13, and the robust F statistic is 0.16 (Montiel-Olea and Pflueger, 2013), much lower than the rule of thumb of at least 10 to consider an instrument relevant.

Figure 2: Response of real copper price, World and Chilean refined copper production to a copper-specific demand shock



Note: The figure illustrates the impulse response functions of accumulated percentage change of monthly refined copper production and real price of copper to one standard deviation copper-specific demand shock from the SVAR model. Dashed and dotted lines represent the confidence bands of one and two standard deviations respectively. The confidence intervals were computed using a recursive design wild bootstrap with 2000 replications (Goncalves and Kilian, 2004).

II Effects of refined copper price changes in Chile

Copper represents between 30% and 60% of Chilean exported goods and around 12% of the Gross Domestic Product (GDP). An increase in copper prices affects the rest of the Chilean economy through different channels. First, higher incomes coming from copper exports generate an income effect that raises demand for goods and services, but it may reduce the labor supply, because households may demand more leisure and spend fewer hours working. Copper price increases can also produce an appreciation of the real exchange rate through the rise of domestic prices and appreciation of nominal exchange rates, making foreign goods cheaper and potentially producing a substitution effect that reduces demand for Chilean non-copper tradable goods.

Increases in copper prices can generate an expansion or contraction depending on the strength of each channel, then the empirical estimation of the effects of copper price changes provides insights about the channels involved. I estimate the dynamic effects of average price changes produced by copper-specific demand shocks on sectoral GDP and exports in the Chilean economy using an IV local projection model. Chilean supply shocks can be related to changes coming from other Chilean sectors. Additionally, shocks related to world economic activity directly affect copper prices and exports from other sectors in the Chilean economy, making it unable to interpret those changes coming only from the copper market.

II.A. The IV local projection model

I estimate the effect of real refined copper price changes on economic outcomes in Chile with an IV local projection model using quarterly average copper specific-demand shocks as instruments for copper price changes[18]:

$$\Delta y_{t+h} = \delta + \alpha_h \Delta P_t^{copper} + \beta_h X_t + \mu_{t+h} \; for \; h \in (1,2...) \tag{2}$$

α_h measures the effect of quarterly percentage change of the average real price of refined copper (ΔP_t^{copper}) coming from the copper-specific demand shock on percentage changes of the outcome of interest h quarters later ($\Delta y_{t+h} = (y_{t+h} - y_{t-1})/y_{t-1}$). I use as instruments the contemporaneous and 1 lag of quarterly average of copper-specific demand innovations.[19] The control variables X_t include one lag of the outcome variable, time trend, and quarterly dummies. I compute Newey West standard error for the coefficient of interest α_h. The data related to Chilean national accounts, prices, exchange rates, and external variables come from the Central Bank of Chile, while the National Statistics Institute of Chile provides data about employment, wages, and hours worked. The sample period is from the first quarter of 1997 to the third quarter of 2018.

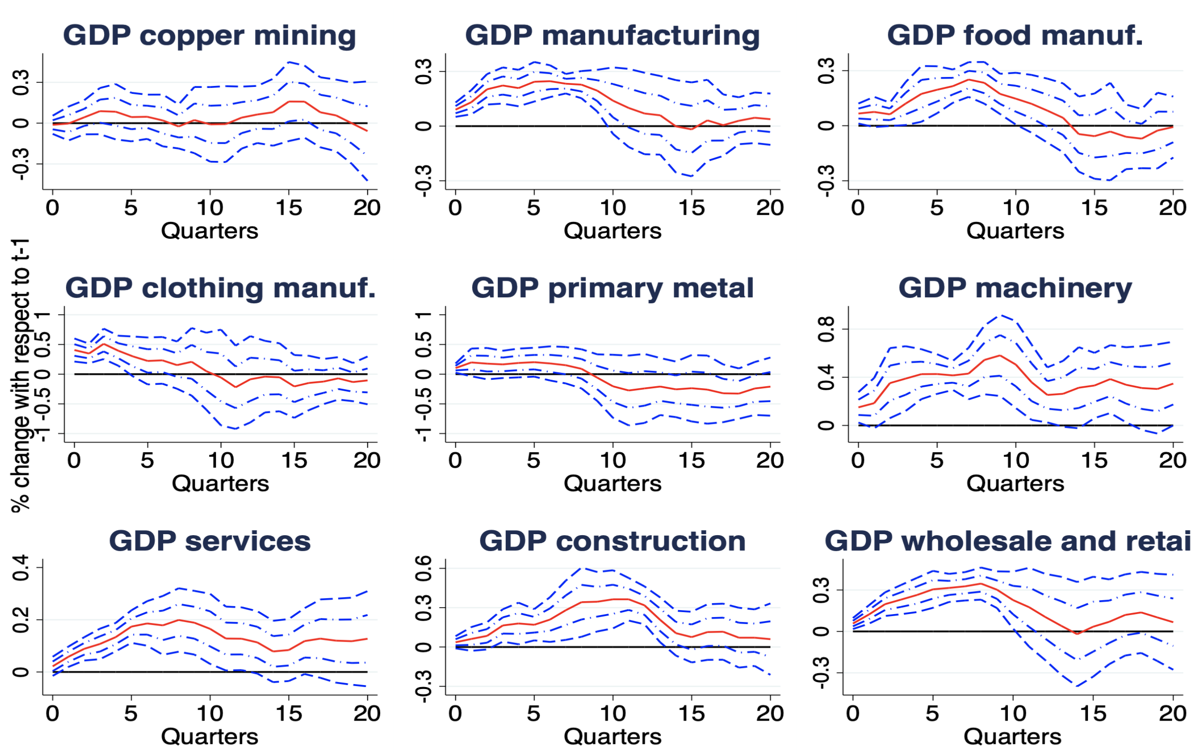
[18]Because outcomes of interest are on a quarterly basis, I use as an instrumental variable the quarterly average of copper-specific demand shocks recovered from the SVAR, computed as $shock_t = \frac{1}{3}\sum_{i=1}^{3} \varepsilon_{t,i}^{demand\ shock}$. $\varepsilon_{t,i}^{demand\ shock}$ for each month i within quarter t.

[19]I compute the weak instrument test proposed by Montiel-Olea and Pflueger (2013). The contemporaneous and 1 lag of the quarterly average copper-specific demand shock are relevant instruments for the IV local projection specification at 5% of significance. Supply shocks coming from other countries besides Chile are not a relevant instrument for copper price changes. See section I about World copper market shocks for further analysis.

II.B. Empirical results

Figure 3 shows the impulse response of the quarterly GDP growth *h* quarters after a one percent variation of real copper price produced by a positive copper-specific demand shock. The solid red lines are the impulse responses, and the dashed and dashed dot lines represent confidence intervals of 1 and 2 standard deviations respectively. The confidence intervals are computed using the Newey-West standard errors.

Figure 3: Response of sectoral GDP to copper prices changes coming from copper-specific demand shocks

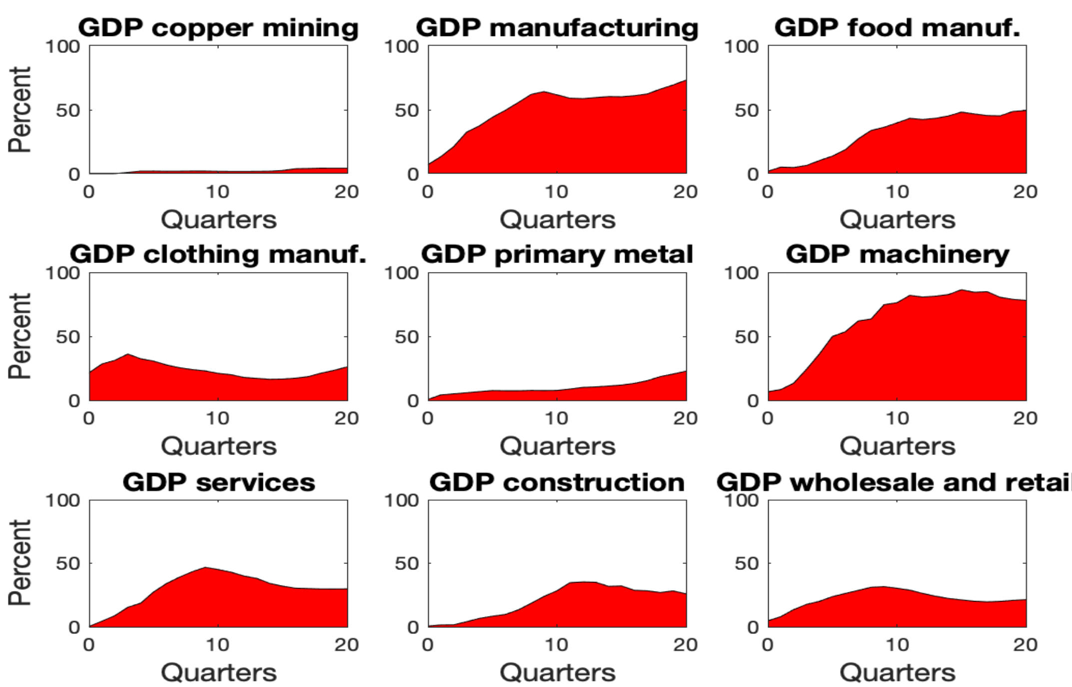


Note: The figure shows the impulse response functions (IRF) of accumulated percentage changes of real GDP to a percentage change of real copper price coming from copper-specific demand shocks. I estimate these IRFs with an IV local projection model, in which the F statistic of the First stage regression is 22.27 and the robust F statistic is 23.09 (see Montiel-Olea and Pflueger, 2013), significant at 5%. The dashed and dotted lines represent the confidence bands to one and two standard deviations respectively, which are heteroskedastic and autocorrelation consistent (HAC) robust.

Changes in real copper prices coming from copper-specific demand shocks produce an expansion across most of the sectors in the Chilean economy, except for the copper industry. As I explain in the international copper market analysis section, copper supply is very inelastic because it relies on the availability of mines to produce copper.

The sectoral expansion produced by copper price changes coming from copper-specific demand shocks is also economically significant, as Figure 4 indicates. Copper price changes coming from copper-specific demand shocks explain around 60% of non-predicted changes in GDP manufacturing and almost 50% of non-predicted changes in GDP services after two years. Additionally, variations in copper prices only explain a small fraction of unexpected changes in GDP copper mining, which implies changes in production are strongly determined by regulations and other productive reasons.

Figure 4: Forecast error variance decomposition for sectoral GDP with local projections



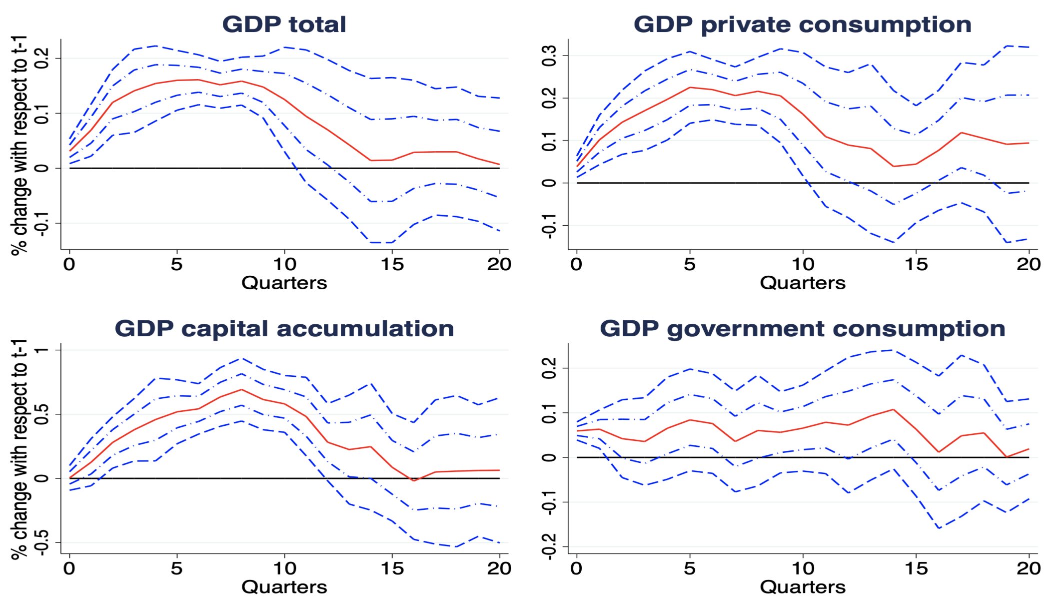
Note: The red area represents the percentage of forecast error explained by copper-specific demand shocks across quarters, using the method proposed by Gorodnichenko and Lee (2020). Plagborg-Moller and Wolf (2022) provide conditions for forecast error variance decomposition using instrumental variables methods.

The expansion of manufacturing is supported by sectors with productive relations with the copper sector, such as machinery, along with sectors without productive relations, such as food and clothing manufacturing.[20] Furthermore, copper price changes coming from copper-specific demand shocks explain a high percentage of variability across sectors, explaining around 50% of

[20]Tables 8 and 9 in Appendix III show the input-output relation between the copper industry and other sectors of the Chilean economy for 1996 and 2013.

non-predicted changes in food manufacturing and more than 80% in machinery production after 3 years. The expansion of manufacturing output represents evidence against the Dutch disease hypothesis about a negative relationship between natural resources windfall and outcomes from manufacturing sectors.

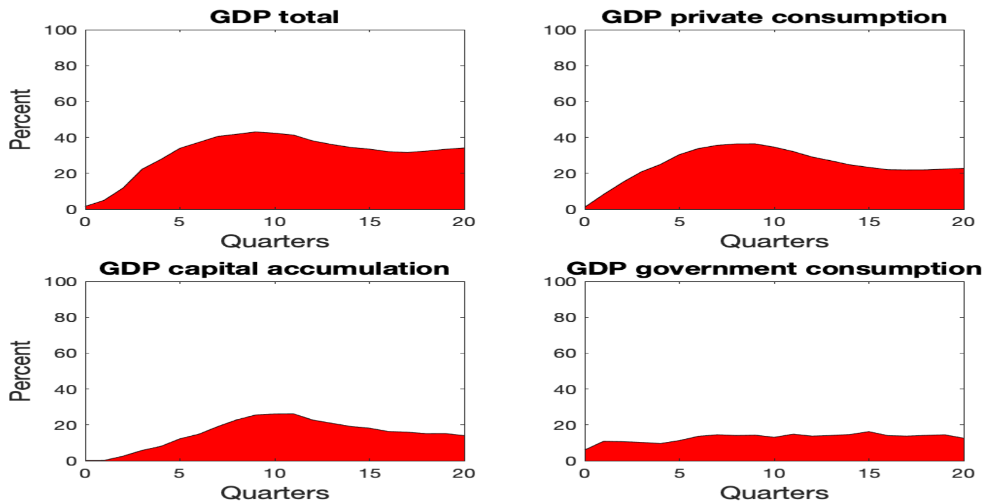
Figure 5: Response of aggregate GDP to copper prices changes coming from copper-specific demand shocks



Note: The figure shows the impulse response functions (IRF) of accumulated percentage changes of real GDP to a percentage change of real copper price coming from copper-specific demand shocks. I estimate these IRFs with an IV local projection model, in which the F statistic of the First stage regression is 21.17 and the robust F statistic is 22.46 (see Montiel-Olea and Pflueger, 2013), significant at 5%. The dashed and dotted lines represent the confidence bands to one and two standard deviations respectively, which are heteroskedastic and autocorrelation consistent (HAC) robust.

Additionally, increases in copper prices produce an expansion of private consumption, investment, and GDP total, as Figure 5 indicates, which is evidence of a predominant income effect on demand for goods, which drives an expansion across sectors and the overall economy. The forecast error variance decomposition illustrated in Figure 6 indicates that Copper price changes coming from copper-specific demand shocks are one of the main determinants of business cycles in Chile, explaining around 40% of non-predicted changes in GDP and private consumption, as well as 30% of capital accumulation, which is similar to Fernandez et. al (2018) findings. Copper price changes produce a small increase in government consumption during the first 6 months after the shock and explain less than 20% of non-predicted changes in government consumption, which implies government spending is not an important explanatory variable for the procyclicality between copper prices and GDP total.[21]

Figure 6: Forecast error variance decomposition for aggregate GDP with local projections



Note: The red area represents the percentage of forecast error explained by copper-specific demand shocks across quarters, using the method proposed by Gorodnichenko and Lee (2020). Plagborg-Moller and Wolf (2022) provide conditions for forecast error variance decomposition using instrumental variables methods.

The positive income effect on demand for goods also drives an increase in total real imports, as Figure 7 illustrates. Although there is an appreciation of the real exchange rate[22], which contributes to an expansion of imports and a contraction of net exports. An increase in copper price enlarges total real exports.[23]

Figure 8 reveals export expansion is held by manufacturing sectors with some productive relation with the copper industry, such as primary metal processing and machinery, while other sectors, such as food manufacturing, do not change significantly.[24] This indicates that changes in the real exchange rate related to copper price variations do not produce a significant decrease in exports.

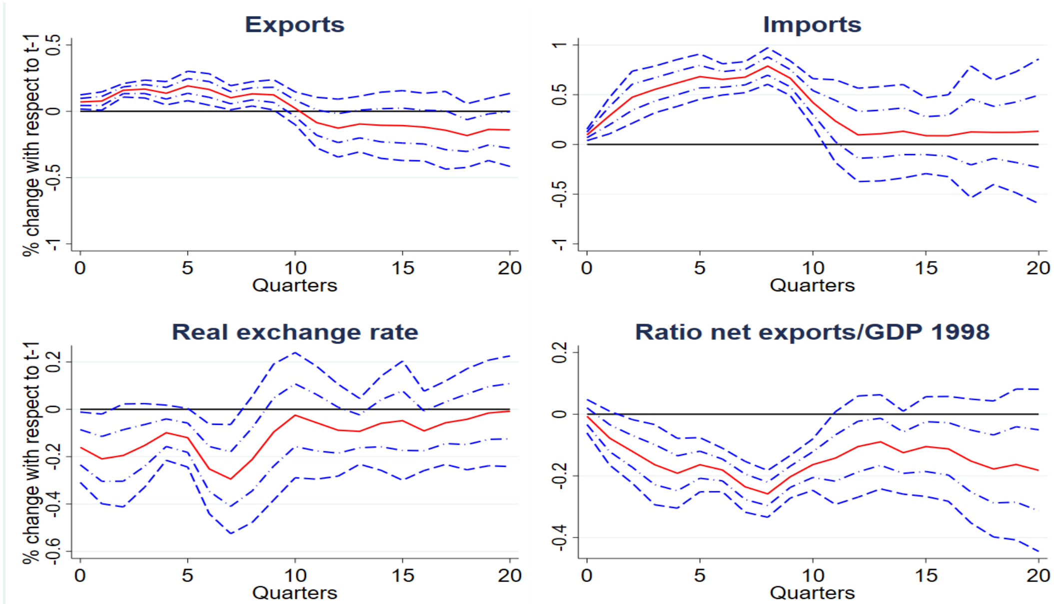
[21]Chile has a fiscal policy of structural balance, which budget is based on expected levels of fiscal revenues in the long run. See Medina and Soto (2016)

[22]Copper-specific demand shocks are an important determinant of the real exchange rate, explaining more than 30% of non-predicted changes after two years. See Figure 27 in Appendix IV.

[23]Net exports are the difference between exports and imports. A reduction in net exports is related to the increase in the gap between imports and exports.

[24]See Appendix III to see the input-output relation between the copper sector and other sectors in the Chilean economy. Additionally, Figure 28 in Appendix IV indicates that copper-specific demand shocks explain almost 50% of changes in exported machinery after three years while explaining less than 20% of exports without productive linkages such as foods manufacturing and wines.

Figure 7: Response of exports, imports and real exchange rate to copper prices changes coming from copper-specific demand shocks



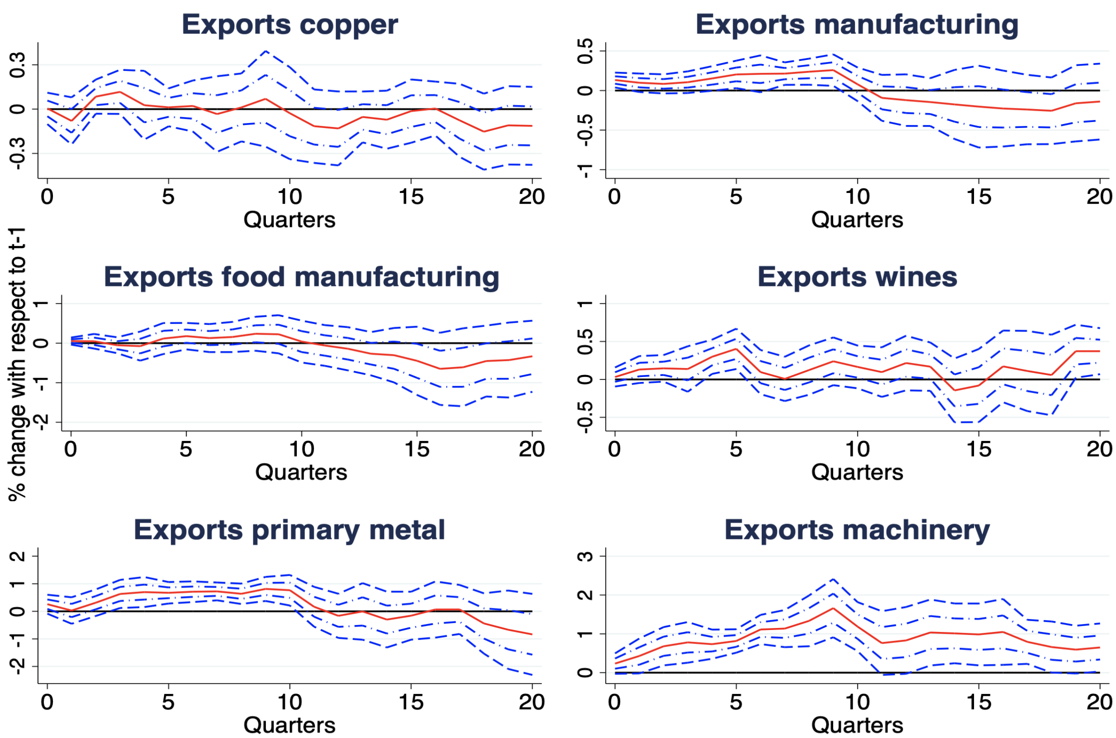
Note: The figure indicates the impulse response functions (IRF) of accumulated percentage changes of real exchange rate, and real values of total exports, imports, and net exports to a percentage change of real copper price coming from copper-specific demand shocks. I estimate these IRFs with an IV local projection model, in which the F statistic of the First stage regression is 29.95, and the robust F statistic is 34.144 (see Montiel-Olea and Pflueger, 2013), significant at 5%. The dashed and dotted lines represent the confidence bands to one and two standard deviations respectively, which they are heteroskedastic and autocorrelation consistent (HAC) robust.

Additionally, copper exports do not react significantly to increases in refined copper prices, because copper supply is also inelastic.

Expansion of hours worked in the manufacturing and services sectors support sectoral GDP expansion during the first 2 quarters after the expansion of copper prices, which is reinforced by an increase in the number of hired workers in the service sector between 1 and 3 years after a copper price rise. An increase in real wages is evidence of the expansion of demand for hours worked across sectors to expand production.

The rise in wages and hours worked increases household incomes and propels the income effect on goods produced by higher copper prices. Furthermore, higher wages and hours worked reveal that the income effect on labor supply is not strong enough to overcome the substitution effect associated with higher salaries and more expensive opportunity costs of leisure, sustaining the

Figure 8: Response of sectoral exports to copper prices changes coming from copper-specific demand shocks



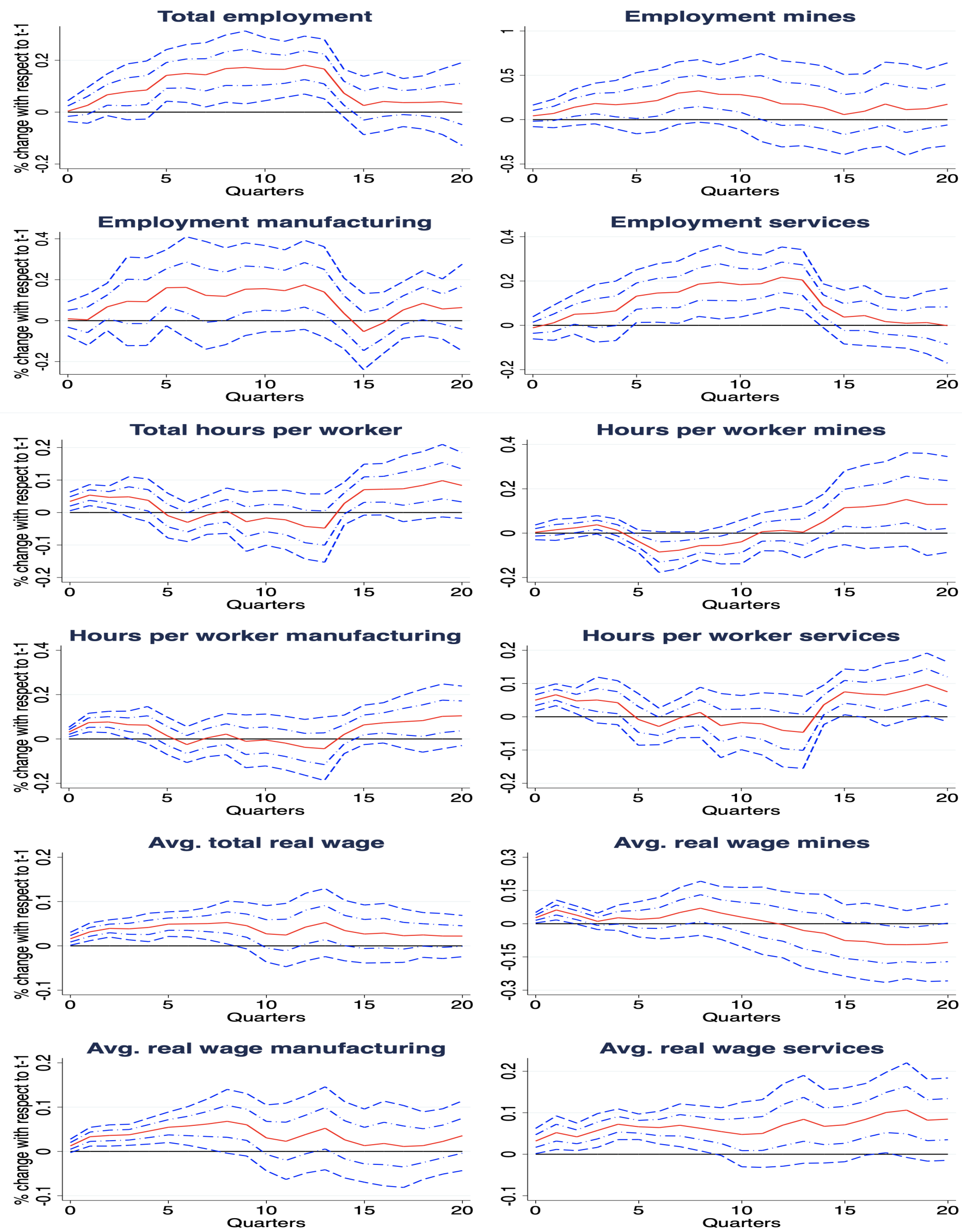
Note: The figure shows the impulse response functions (IRF) of accumulated percentage changes of real values of exports to a percentage change of real copper price coming from copper-specific demand shocks. I estimate these IRFs with an IV local projection model, in which the F statistic of the First stage regression is 24.11 and the robust F statistic is 23.61 (see Montiel-Olea and Pflueger, 2013), significant at 5%. The dashed and dotted lines represent the confidence bands to one and two standard deviations respectively, which are heteroskedastic and autocorrelation consistent (HAC) robust.

expansion of the economy.[25]

The rise of refined copper price coming from copper-specific demand shocks produces an income effect that increases the private real consumption and the gross real investment, leading to an expansion of GDP in most sectors and imports. Furthermore, the output expansion is driven by sectors with and without productive relations with the copper extraction sector. If we consider that

[25] Moreover, copper-specific demand shocks are an important determinant of movement in employment, explaining around 30% of non-predicted changes in the number of workers in manufacturing, services, and the overall economy after 4 years. Similarly, copper-specific demand shocks explain around 40% of non-predicted changes in the overall economy and services average real wages. However, these shocks only explain less than 10% of non-predicted changes in hours per worker. See Figure 29 in Appendix IV.

Figure 9: Response of labor market outcomes to copper prices changes coming from copper-specific demand shocks



Note: The figure reveals the impulse response functions (IRF) of accumulated percentage changes of the number of employed people, average hours per worker, and real average wages deflated by core CPI to a percentage change of real copper price coming from copper-specific demand shocks. I estimate these Impulse Response Functions with an IV local projection model, in which the F statistic of the first stage regression is 22.36, and the robust F statistic is 21.63 (see Montiel-Olea and Pflueger, 2013), significant at 5%. The dashed and dotted lines represent the confidence bands to one and two standard deviations respectively, which are heteroskedastic and autocorrelation consistent (HAC) robust.

demand shock does not produce a significant change in GDP copper, then the output expansion of non-copper tradable and non-tradable sectors is produced predominantly by an income effect for goods and services. Despite the real exchange rate appreciation, there is no evidence of a contraction of the non-copper tradable GDP and exports fueled by a reallocation of labor from non-copper tradable sectors to the rest of the economy, as Corden and Neary (1982) predicts. Additionally, there is no evidence of a strong income effect on labor supply that makes households demand more leisure, reducing the supply of hours worked.

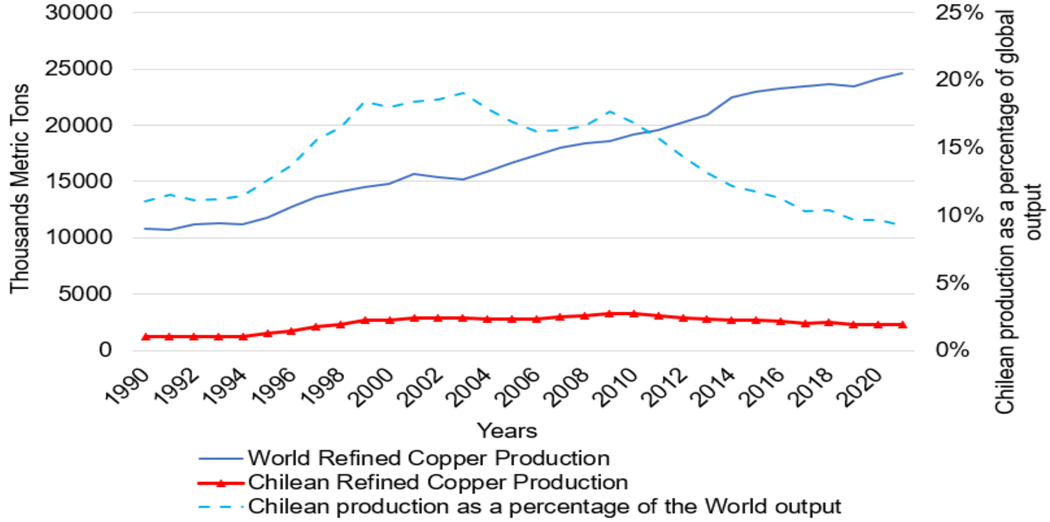
Despite these empirical estimations highlighting copper price changes produced by copper-specific demand shocks generate an expansionary income effect on demand for goods, we cannot infer how the substitution effect related to changes in the real exchange rate and the strength of income effect on labor supply may drive the effect of commodity price shocks. To answer these questions, I estimate a small open economy (SOE) model with impulse response function matching using the empirical estimations from this section. The estimated SOE model provides insights into how substitution and income effects determine the overall and sectoral effects of commodity price shocks through counterfactual exercises.

II.C. Robustness check

Copper-specific demand shocks could be related to variations in speculative demand for copper associated to changes in expectations. Then changes in the expected production from Chile may affect the speculative demand for copper. However, the production of refined copper in Chile did not expand between 2000 and 2021, very different from the growing pattern of the world refined copper production, as the figure 10 shows. This feature provides evidence that changes in the production of copper in Chile had a low impact in the variation of the world production between 2000 and 2021, which also imply that a change in the expected production in Chile had a low impact on the expected world supply in this period.

The appendix V shows the estimations using data since 2000. Estimation from this shorter database shows the same conclusions than the main results in most of the outcomes. The only exception are the response of employment in mines and manufacturing, which the results using the database since 2000 are more significant for certain quarters than the main results. Overall, these results provide evidence that changes in the expectation on Chilean refine copper supply are not an important driver of the copper-specific demand shocks and previous empirical results.

Figure 10: World and Chilean refined copper production



Note: The figure shows the refined copper in thousands of metric tons in Chile and the World. The percentage shows the ratio between Chilean and world refined copper production.
Source: Chilean Commission of Copper (Cochilco)

III The small open economy model

The small open economy is inhabited by a large number of identical households that sell hours worked and rent capital to three sectors in the economy: Non-commodity tradable (nc), commodity (co), and non-tradable (nt) sectors to produce homogeneous goods each one. Three sectors produce composite homogenous goods combining domestic and imported products.

Imported goods are combined with non-commodity tradable products to produce importable composite goods. Producers of importable composite goods sell their product to producers that combine this input with commodity goods to produce tradable composite goods, which are sold to final goods producers that combine them with non-tradable goods. Households buy final goods for consumption and investment.

Commodity and non-commodity tradable sectors can export their products, while the rest of the sectors only produce for domestic use. Commodity prices are exogenous to the small open economy. A positive commodity price shock increases the value of commodity exports and incomes of the commodity sector, rising incomes perceived by households. The effect of commodity shocks in the economy depends on the income effect on goods that positively affects the demand for final goods and the income effect on labor that negatively affects the supply of hours worked by households. The appreciation of the real exchange rate related to commodity price changes makes foreign goods cheaper, producing a substitution effect between non-commodity tradable and foreign goods.

III.A. Households

Each identical household i maximizes its lifetime utility defined over sequences of consumption (c_t^i) and hours worked ($h_t^{i,j}$) in sectors $j \in nc, co, nt$. Their preferences are non-time separable between hours worked and consumption. These preferences are based on Jaimovich and Rebelo (2009). The utility function for household i is:

$$U(c_t^i, h_t^{i,nc}, h_t^{i,co}, h_t^{i,nt}) = E_0 \sum_{t=0}^{\infty} \beta^t \frac{[c_t^i - \frac{1}{\psi}(h_t^{i,nc} + h_t^{i,co} + h_t^{i,nt})^{\psi} x_t^i]^{1-\sigma}}{1-\sigma} \tag{3}$$

Where $x_t^i = c_t^{i\gamma} (x_{t-1}^i)^{1-\gamma}$. γ governs the size of the income effect. When $\gamma = 0$, the utility function converges to GHH preferences with no income effect on labor supply. The parameter ψ measures the sensitivity of the utility function to the total number of hours worked.

Households maximize their utility subject to the sequential budget constraint:

$$c_t^i + i_t^i + \sum_j s^h(h_t^{i,j}/h_{t-1}^{i,j}) + e_t a_t^i = e_t(1 + i_t^f) a_{t-1}^i + \sum_j [w_t^j h_t^{i,j} + r_t^j K_t^{i,j}] + \sum_l \pi_t^{i,l}$$

They earn a salary (w_t^j) for each hour sold and rent (r_t^j) for each unit of capital ($K_t^{i,j}$) leased to firms in sectors $j \in nc, co, nt$. They also receive profits ($\pi_t^{i,l}$) from all productive sectors of the economy. Households accumulate assets a_t^i valued in foreign currency that generate a return i_t^f each period. The value of the exchange rate (e_t) affects the value of foreign assets in domestic currency. Household i faces adjustment cost when hours worked changes:

$$s_h\left(\frac{h_t^{i,j}}{h_{t-1}^{i,j}}\right) = \frac{\Phi_j^h}{2}\left(\frac{h_t^{i,j}}{h_{t-1}^{i,j}} - 1\right)^2 \tag{4}$$

Household i accumulates aggregate capital investing i_t^i each period. The law of motion of total capital is:

$$k_t^i = (1-\delta) * k_{t-1}^i + i_t^i\left(1 - s\left(\frac{i_t^i}{i_{t-1}^i}\right)\right) \tag{5}$$

I assume adjustment cost on investment in the following form $s(i_t/i_{t-1}) = \frac{\Phi^{tot}}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2$, which $\Phi^{tot} > 0$ is the adjustment cost parameter and depreciation rate δ is between 0 and 1. There is no adjustment cost in the steady state.

III.B. The tradable non-commodity, commodity, and non-tradable sectors

Competitive representative firms from sector $j \in \{nc, co, nt\}$ produce homogeneous goods using capital and hours worked with the following production function:

$$y_t^j = A^j (K_{t-1}^j)^{\alpha_j} (h_t^j)^{1-\alpha_j} \tag{6}$$

A^j is a sector-specific and time-invariant level of productivity and $\alpha_j \in [0,1]$ is the output elasticity of capital. $1-\alpha_j \in [0,1]$ is the output elasticity of hours worked. Firms take the price of output (p_t^j) and the price of inputs as given, maximizing profits by solving:

$$\max_{h_t^j, K_{t-1}^j \geq 0} \pi_t^j = p_t^j y_t^j - w_t^j h_t^j - r_t^j K_{t-1}^j \tag{7}$$

Firms from the tradable non-commodity sector sell their product domestically to importable goods producers and abroad as well. Firms from the commodity sector also export their product and sell the remaining quantities to tradable goods producers. Non-tradable firms only sell their products to final goods producers.

III.C. Demand for non-commodity exports

Trade partners import non-commodity goods from the small open economy, among other countries ($Imp_t^{g,*}(m)$). A foreign sector produces goods ($Imp_t^{g,*}$) with imported inputs using a CES production function:

$$Imp_t^{g,*} = \left[\sum_m Imp_t^{g,*}(m)^{\frac{\eta^\varepsilon - 1}{\eta^\varepsilon}} \right]^{\frac{\eta^\varepsilon}{\eta^\varepsilon - 1}} \tag{8}$$

Their demand for non-commodity exports is $Imp(m)_t^g = \left(\frac{P_t^g}{P(m)_t}\right)^{\eta^\varepsilon} Imp_t^g$. I assume all trade partners have the same elasticity of substitution η^ε. Aggregate demand for non-commodity exports from the small open economy is:

$$xr_t = \sum_{g \varepsilon G} \left(\frac{P_t^{g*}}{p_{e,t}^{nc}} \right)^{\eta^\varepsilon} Imp_t^{g*} = \left(\frac{e_t}{p_t^{nc}} \right)^{\eta^\varepsilon} B^* \tag{9}$$

B^* combines foreign variables and parameters related to trade partners. The foreign elasticity of substitution η^ε determines the impact of exchange rate and prices on non-commodity exports.

III.D. Importable composite goods sector

Competitive representative firms produce importable composite goods combining tradable no commodity goods (a_t^{nc}) bought from the domestic sector and imported goods (imp_t) using a production function with constant elasticity of substitution (CES):

$$y_t^m = A(y_t^{nc}, imp_t) = A^m \left[\chi^m (a_t^{nc})^{\frac{\eta_{nc}-1}{\eta_{nc}}} + (1-\chi^m)(imp_t)^{\frac{\eta_{nc}-1}{\eta_{nc}}} \right]^{\frac{\eta_{nc}}{\eta_{nc}-1}} \tag{10}$$

which η_{nc} is the elasticity of substitution between the tradable non-commodity goods and imports, and χ^m determines the relative weight of domestic and imported goods. Producers of importable goods are price takers, selling at price p_t^m. Firms decide the demand for inputs according to profit maximization. e_t is the exchange rate and P_t^* is the price of imports in foreign currency:

$$\max_{y_t^{nc}, imp_t \geq 0} \pi_t^m = p_t^m A(a_t^{nc}, imp_t) - p_t^{nc} a_t^{nc} - e_t P_t^* imp_t \tag{11}$$

From first order condition profit maximization problem, demand for non-commodity exports is:

$$a_t^{nc} = \left(\frac{1-\chi_m}{\chi_m} \right)^{\eta^{nc}} \left(\frac{e_t}{p_t^{nc}} \right)^{\eta^{nc}} imp_t \tag{12}$$

The elasticity of substitution η^{nc} is key for the impact of exchange rate and price on domestic demand for tradable non-commodity goods.

III.E. Tradable composite good sector

Firms from the commodity sector sell the fraction of commodity goods (a_t^{co}) sold domestically to the tradable composite good producers, which combine them with importable composite goods (a_t^m) using a CES production function.

$$y_t^t = A(a_t^m, a_t^{co}) = A^t \left[\chi^t (a_t^m)^{\frac{\eta_t-1}{\eta_t}} + (1-\chi^t)(a_t^{co})^{\frac{\eta_t-1}{\eta_t}} \right]^{\frac{\eta_t}{\eta_t-1}} \tag{13}$$

η^t is the elasticity of substitution between commodity and importable composite goods, and χ^t is the relative weight of importable goods input. Producers of tradable goods are price takers that sell at price p_t^t and choose the production level that maximizes profits:

$$\max_{y_t^t, y_t^m \geq 0} \pi_t^t = p_t^t A(a_t^m, a_t^{co}) - p_t^m a_t^m - p_t^{co} a_t^{co} \tag{14}$$

III.F. Final good sector

Competitive firms of final goods combine tradable composite goods (a_t^t) and non-tradable goods (a_t^{nt}) to produce final goods with a CES production function.

$$y_t^c = A(a_t^t, y_t^{nt}) = A^c \left[\chi^c (a_t^t)^{\frac{\eta_c - 1}{\eta_c}} + (1 - \chi^c)(a_t^{nt})^{\frac{\eta_c - 1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}}$$

where η_c is the elasticity of substitution between tradable and non-tradable goods, and χ^c determines the relative weight of tradable goods. The price of final goods is normalized. Producers of final goods maximize profits:

$$\max_{a_t^t, y_t^{nt} \geq 0} \pi_t^c = A(a_t^t, y_t^{nt}) - p_t^t a_t^t - p_t^{nt} a_t^{nt}$$

III.G. Market clearing and current account

Final good producers sell their goods to households for consumption, aggregate investment, and adjustment cost of hours worked in each sector. The market clearing condition for the final good is:

$$Y_t^c = c_t + i_t^{tot} + \sum_{j \; \varepsilon \; nc, co, nt} s^h(h_t^j / h_{t-1}^j) \tag{15}$$

Commodity and non-commodity tradable firms sell their products domestically (a_t^j) and abroad (xr_t^j). The market clearing conditions are:

$$Y_t^j = a_t^j + xr_t^j \; for \; j \; \in \; nc, co \tag{16}$$

Non-tradable firms, importable and tradable composite goods producers only sell their goods domestically. The market clearing conditions for these domestic markets are:

$$Y_t^l = a_t^l \; for \; l \; \in \; nt, m, t \tag{17}$$

The trade balance of this open economy affects the net foreign asset position. Then, the net foreign asset accumulation depends on the current account:

$$\begin{gathered} a_t = x_t^{nc} + x_t^{co} - m_t + (1 + i_t^d) a_{t-1} \Rightarrow \\ a_t = p_{e,t}^{nc}(y_t^{nc} - a_t^{nc}) + p_{e,t}^{co}(y_t^{co} - a_t^{co}) - p_t^* imp_t + (1 + i_t^d) a_{t-1} \end{gathered} \tag{18}$$

Export is the value in foreign currency of tradable commodities and non-commodity goods sold abroad ($x_t^j = p_{e,t}^j(y_t^j - a_t^j)\ for\ j \in nc, co$), and imports is the value of imported goods in foreign currency ($m_t = p_t^* imp_t$).[26] Additionally, following Schmitt-Grohé and Uribe (2003), the country's interest rate depends on total foreign assets to ensure a stationary process and governs interest rate movements coming from foreign assets accumulation.

$$i_t^d = r^* + p(a_t) \tag{19}$$

r_t^* is the risk free world interest rate, $p(a_t) = \omega(e^{(\bar{a}-a_t)} - 1))$ is the domestic component of the interest rate spread that depends on the stock of the foreign traded asset, which $\bar{a}$ is equal to the steady state of net assets. If the net assets increase, the interest rate decreases.

The value of the foreign traded assets in domestic currency is determined by the exchange rate. From the Euler equation of asset accumulation, the value of the exchange rate is determined by the future path of interest rate:

$$e_t = \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} e_{t+1}(1 + i_{t+1}^d) \right] = E_t \left[\beta^k \prod_{k=0}^{\infty} \left(\frac{\lambda_{t+k+1}}{\lambda_{t+k}} \right) (1 + i_{t+k+1}^d) e_{LR} \right] \tag{20}$$

e_{LR} is the exchange rate in the long run. Finally, I assume the commodity price is exogenous and follows an AR(1) process.[27]

$$p_t^{co} = \rho_{co} p_{t-1}^{co} + \varepsilon_t^{co} \tag{21}$$

III.H. Definition of equilibrium in the small open economy

Conditional on sequences of exogenous international commodity prices $\{p_t^{co}\}_{t=0}^{\infty}$, prices of foreign goods, and risk free world interest rate, the equilibrium of this small open economy is defined by a sequence of aggregate allocations $\{c_t,\ i_t^{tot},\ K_t,\ a_t\ Imp_t\}_{t=0}^{\infty}$, a sequence of allocations $\{h_t^j,\ K_{t-1}^j,\ y_t^j\}_{t=0}^{\infty}$ in sectors $j \in \{nc, co, nt\}$, sectoral allocations $\{a_t^l\}_{t=0}^{\infty}$ for $l \in \{nc, co, nt, m, t\}$ and $\{xr_t^o\}$ for $o \in \{nc, co\}$, a sequence of prices $\{w_t^j, r_t^j\}_{t=0}^{\infty}$ for $j \in \{nc, co, nt\}$ and $\{p_t^l\}_{t=0}^{\infty}$ for $l \in \{nc, co, nt, m, t\}$, a sequence of exchange rates $\{e_t\}_{t=0}^{\infty}$ and interest rates $\{i_t^f\}_{t=0}^{\infty}$ such that (i) Households solve their utility maximization problem, (ii) Firms maximize their profits, and (iii) All markets clear.

[26] I normalize the price of imported goods in foreign currency p_t^*.

[27] Although Chile is the biggest exporter of refined copper in the world, the analysis of the World refined copper market indicates Chilean supply shocks do not produce a significant change in real copper prices (see Appendix II). Then the assumption of a commodity price process exogenous to the small open economy is valid.

IV Estimation of the SOE model

I use the method proposed by Christiano, Eichenbaum, and Evans (2005) to minimize the distance between empirical impulse responses from a local projection using the copper-specific demand shock as an explanatory variable directly and the theoretical impulse response from the log linearized SOE model around the steady state. The minimum distance expression is:

$$arg\ min_{\psi,\phi_j,\phi_j^h,\eta_k,\gamma,\rho_{co},\sigma_\varepsilon^2}\left[IR^e - IR^m(\psi,\phi_j,\phi_j^h,\eta_k,\gamma,\rho_{co},\sigma_\varepsilon^2)\right]W\left[IR^e - IR^m(\psi,\phi_j,\phi_j^h,\eta_k,\gamma,\rho_{co},\sigma_\varepsilon^2)\right] \quad (22)$$

Which W is the inverse of the diagonal matrix containing the variance of the empirical impulse response function along the diagonal. I estimate key parameters such as the elasticity of substitution between domestic and foreign goods,[28] price elasticity for non-commodity exports,[29] and parameters associated with labor supply[30] and adjustment costs, among other parameters. I match impulse response functions for consumption, investment, sectoral GDP, sectoral exports, imports, current account, sectoral real wages, and sectoral hours worked.

Table 1 shows the calibrated parameters based on standard values of the literature of commodity price shocks, terms of trade shocks, and business cycles in small open economies. The inverse of the real world interest rate is the value of the discount factor of households, following Fernández et al. (2018), as well as the relative risk aversion coefficient from the same model. The depreciation of physical capital is the quarterly adjusted value used by Schmitt-Grohé and Uribe (2018) as well as I use the capital share for non-commodity tradable and non-tradable sectors from the same paper too. The capital share for commodity production is the value estimated by Aguirregabiria and Luengo (2016) for copper production.

I compute the input weight of domestic non-commodity goods used by the importable composite good sector as the proportion of domestic manufacturing inputs with respect to total manufacturing inputs used in the Chilean economy according to the input-output matrix estimated for 1996. Similarly, I use the Chilean input-output matrix to compute the weight of importable composite goods used by the tradable composite sector and the weight of tradable composite goods used by final goods producers. I compute the weight of importable goods as the proportion of non-copper as a total of non-service inputs, while the weight of tradable composite goods is the proportion of non-service inputs used in the Chilean economy.

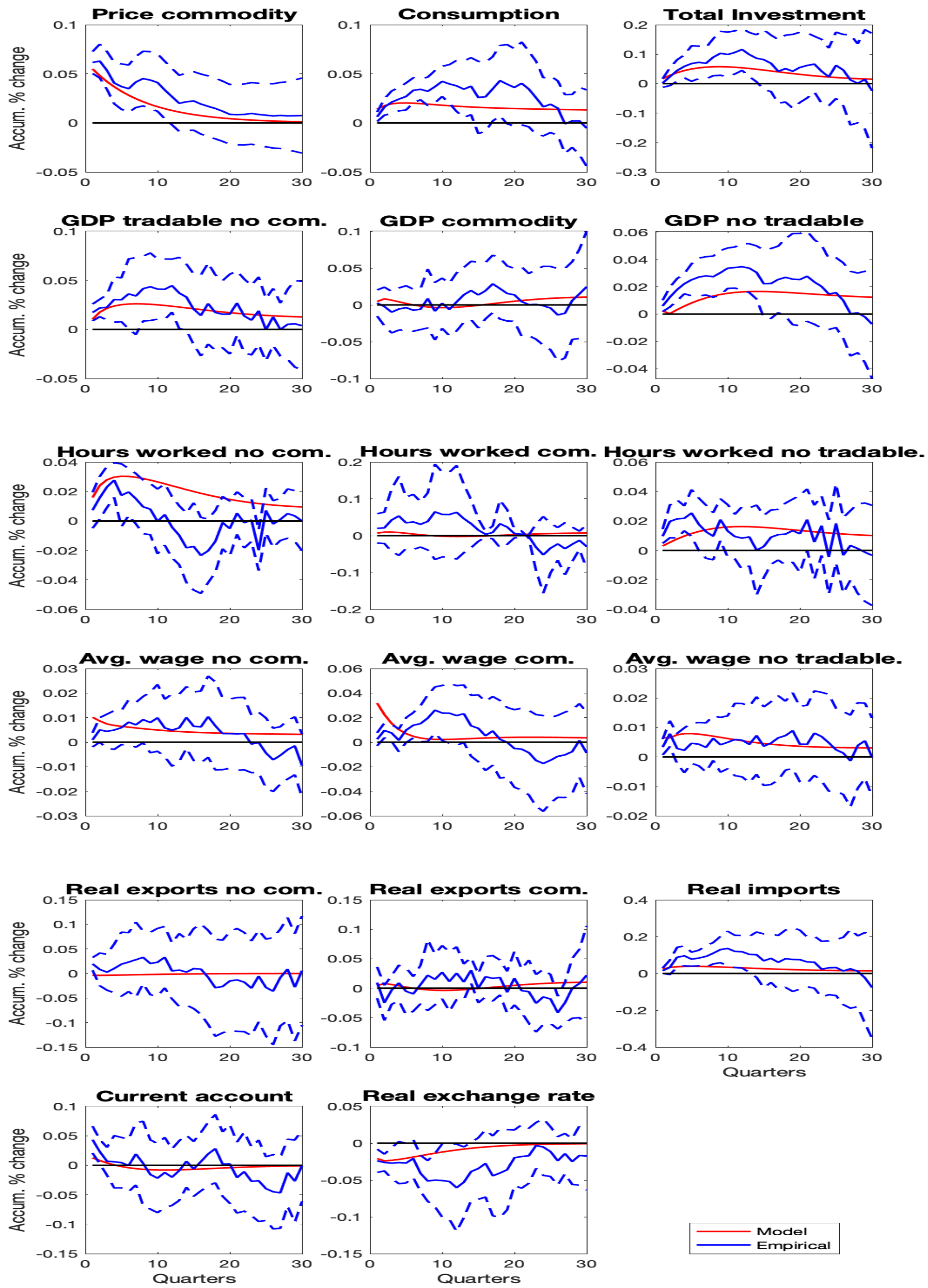
Table 2 shows estimates of parameters coming from impulse response matching estimation. I

[28] This is the input elasticity of substitution and price elasticity η_{nc} from equations 10 and 12 respectively.

[29] This is the elasticity of substitution and price elasticity η_ε from equations 8 and 9 respectively.

[30] Parameters ψ and γ from the utility function.

Figure 11: Goodness of fit of the impulse response function matching estimation



Note: The red line represents the impulse response function coming from the estimated SOE model with the impulse response matching method. The blue line is the local projection impulse response function (LP IRF) used for the matching estimation and the dotted lines represent the confidence bands to two standard deviations around the empirical impulse response, which are computed using standard errors heteroskedastic- and autocorrelation-consistent (HAC) robust. The tradable non-commodity and commodity outputs and exports are matched with GDP and exports from the manufacturing and copper sectors respectively, as well as the non-tradable is matched with the service sector.

Table 1: Calibrated parameters of the SOE model

Par.	Value	Description	Source
β	0.99	Discount factor	Fernández et. al. (2018)
σ	2	Relative risk aversion coefficient	Fernández et. al. (2018)
δ	0.024	Capital depreciation quarterly rate	Schmitt-Grohé and Uribe (2018)
α_{nc}	0.35	Capital share non-commodity sector	Schmitt-Grohé and Uribe (2018)
α_{co}	0.332	Capital share commodity sector	Aguirregabiria and Luengo (2016)
α_{nt}	0.25	Capital share non-tradable sector	Schmitt-Grohé and Uribe (2018)
χ^c	0.438	Input weight tradable composite good	Input output matrix (1996)
χ^t	0.914	Input weight importable composite good	Input output matrix (1996)
χ^m	0.454	Input weight domestic non-commodity good	Input output matrix (1996)

Note: The table indicates the value of parameters used in the SOE model coming from the literature related to business cycles in small open economies or calibrated from the Chilean input-output matrix.

Table 2: Estimated parameters of the SOE model

Par.	Coeff. est.	Sd. err.	Description
ρ^{co}	0.875	0.0035	Commodity price persistence
σ_ε	0.055	0.0005	Standard deviation commodity shock
ψ	1.359	0.0105	Labor supply sensitivity parameter
ϕ_{tot}	2.166	0.8302	Adjustment cost of total capital
ϕ^h_{nc}	1.89	0.1067	Adjustment cost of hours worked tradable non-commodity sector
ϕ^h_{co}	14.215	0.5885	Adjustment cost of hours worked commodity sector
ϕ^h_{nt}	14.334	2.755	Adjustment cost of hours worked non-tradable sector
η^c	1.687	0.0039	Elasticity of substitution tradable & non-tradable goods
η^t	2.166	2.1355	Elasticity of substitution importable & exportable goods
η^{nc}	0.252	0.0512	Elasticity of substitution tradable non-commodity & imports
η^e	0.961	0.2933	Elasticity of substitution non-commodity exports
ω	0.014	0.0016	Interest rate sensitivity to assets parameter
γ	0.000	0.0000	Utility parameter for income effect on labor supply

Note: The table shows the estimated parameters using impulse response matching (Christiano et. al. 2005) between impulse responses estimated with local projections and theoretical impulse responses coming from the SOE model. I compute the standard errors with the estimated covariance matrix proposed by Guerron-Quintana et al. (2017).

use the approach suggested by Guerron-Quintana et al. (2017) to estimate standard errors.[31] Additionally, Figure 11 shows the impulse response functions of the estimated theoretical SOE model and their fit with the empirical impulse response function coming from the local projection estimations. The parameter associated with the commodity price process indicates the high persistence of commodity prices to copper-specific demand shocks, which implies commodity price shocks have a prolonged effect on commodity prices and the small open economy. The sensitivity of adjustment cost to hours worked in the commodity sector is higher than in the tradable non-commodity sector, which explains why hours worked, output and exports from the commodity sector respond less than non-commodity tradable sectors to commodity price shocks.

Furthermore, the elasticity of substitution between domestic and imported goods and the price elasticity of non-commodity exports are lower than one, which implies the sensitivity of demands for domestic tradable non-commodity goods to changes in the real exchange rate is small,[32] explaining why GDP expands with no visible decline in the exports of any sector, including manufacturing. Finally, the parameter related to the income effect on labor is zero, which explains there is no income effect on the labor supply and utility function that converges to GHH preferences (see Greenwood et al. 1988).

V Role of elasticities of substitution and income effect on labor supply

The previous section indicates an elasticity of substitution between domestic and foreign goods, and price elasticity for non-commodity exports is lower than one, which explains why increases in copper prices generate an expansion of GDP and no fall of exports in the manufacturing sector. It also shows broad GDP increase across sectors is associated with a null income effect on labor supply. This section analyzes how estimated parameters shape the effect of commodity price shocks comparing the estimated SOE impulse response functions with counterfactuals when the degree of substitution between domestic and foreign goods, and the income effect on labor supply are large.

---

[31]I estimate the asymptotic covariance matrix proposed by Guerron-Quintana et al. (2017). The estimation of the asymptotic variance-covariance matrix is $(F_0^T W F_0)^{-1} F_0^T W \Sigma W F_0 (F_0^T W F_0)^{-1}$, which Σ is the covariance matrix of the empirical response function computed with the block of block bootstrap method (Berkowitz et. al. 1999, Kilian and Kim 2011), W is the inverse of the diagonal matrix of Σ and F_0 is the Jacobian of theoretical impulse response functions evaluated on estimated parameters.

[32]An implication of the Euler equation (equation 20) is net assets accumulation that reduces the path of interest rates generates an appreciation of the real exchange rate.

V.A. Role of elasticity of substitution between domestic tradable non-commodity goods and imports

The degree of substitutability between domestic and imported goods is an important factor that determine the sectoral effect of a commodity price shock. When the elasticity of substitution between domestic and imported goods is large, the demand for domestic tradable non-commodity goods is more sensitive to an appreciation of the real exchange rate. A commodity price shock generates an appreciation of the real exchange rate for two reasons, first because increases the level of prices, which is the denominator of the real exchange rate, and second generates a surplus in the current account, increasing the accumulation of net assets and reducing the asset elastic interest rate that depends on net assets stock, as equation 18 and 19 indicate respectively. The decrease of the values of asset elastic interest rates for the following quarters decreases the exchange rate, as the Euler relation (equation 20) denotes. Then the appreciation associated with a commodity price shock generates a contraction of the GDP tradable non-commodity when the elasticity of substitution is high, as Figure 12 indicates.

Additionally, the contraction of the non-commodity tradable sector reduces the sectoral demand for hours worked and generates a drop in sectoral real wages during the first periods, producing a reallocation of hours worked from the tradable non-commodity sector to the commodity sector, generating a big expansion of GDP and exports of commodity firms. When the elasticity of substitution between domestic and imported goods is high, commodity price shocks generate the Dutch disease, in which the non-commodity tradable sector shrinks, and other sectors expand because of hours worked to move away from the non-commodity tradable sector.

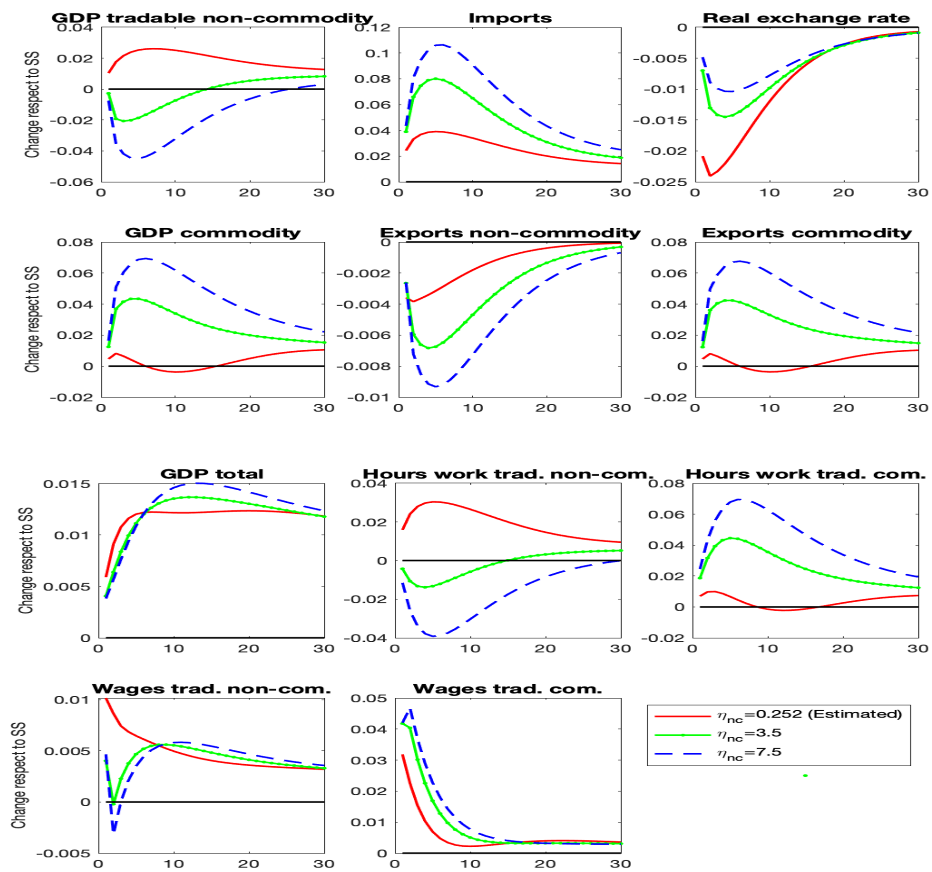
V.B. Role of price elasticity for non-commodity exports

Similarly, to the domestic elasticity of substitution, the price elasticity of the demand for non-commodity exports[33] measures the sensitivity of exports to changes in the real exchange rate. As Figure 13 indicates, when the price elasticity of demand for exports is large, an appreciation of the real exchange rate coming from a commodity price shock generates a big contraction of non-commodity exports, mitigating an expansionary effect of commodity price on GDP tradable non-commodity and even reducing it in the second quarter after the shock.

Additionally, the associated small reaction of hours worked in the non-commodity tradable sector is related to a large expansion of hours worked in the commodity sector, generating a large expansion of GDP and exports in this sector. The Dutch disease is also related to a large price

[33] Subsection III.C. indicates that the price elasticity is the foreign elasticity of substitution among goods imported by trade partners.

Figure 12: Response of SOE model to commodity price shocks for different elasticities of substitution between domestic and imported goods



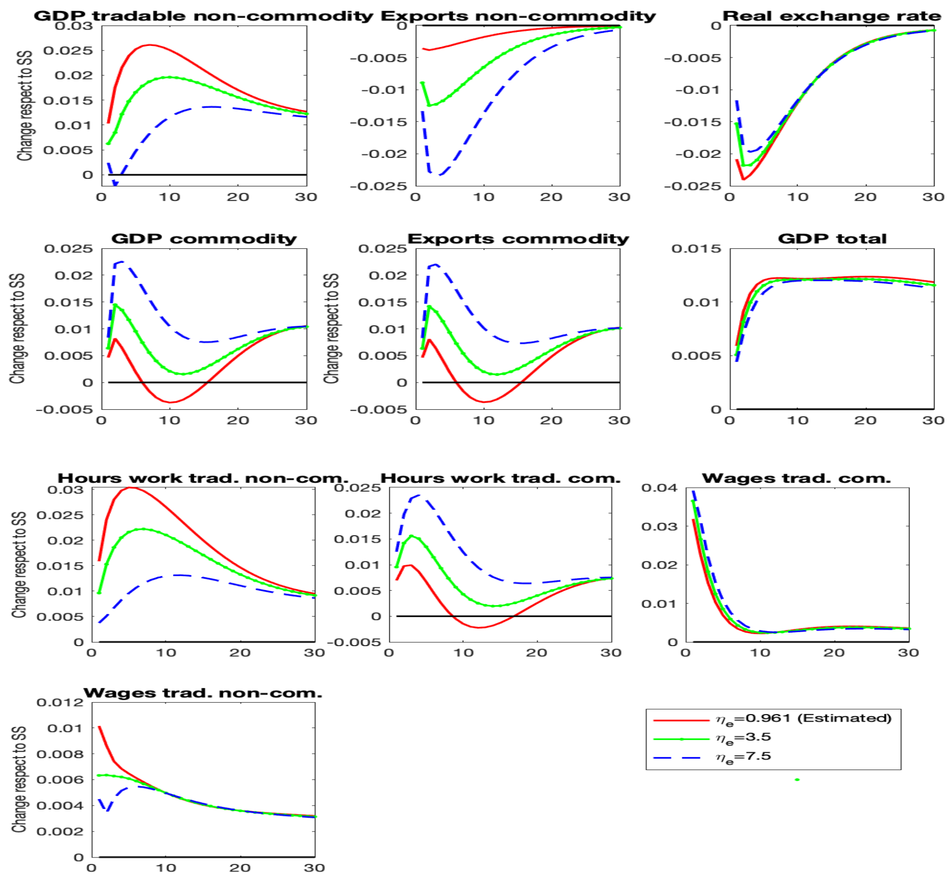
Note: The figure represents impulse response functions from the estimated SOE model, evaluated for different values of the elasticity of substitution between domestic tradable non-commodity and imported goods.

elasticity of demand for exported non-commodity goods.

V.C. Role of income effect on labor supply

A large income effect on labor supply makes real wages highly responsive to commodity price shocks. Despite a large increase in wages when income effect on labor supply is high, the reaction of hours worked is small in the tradable non-commodity sector, while hours worked and GDP in the commodity and non-tradable sectors fall during some quarters because wages in the tradable non-commodity sector increase relatively more than other sectors, producing movement of hours workers from other sectors to tradable non-commodity firms.

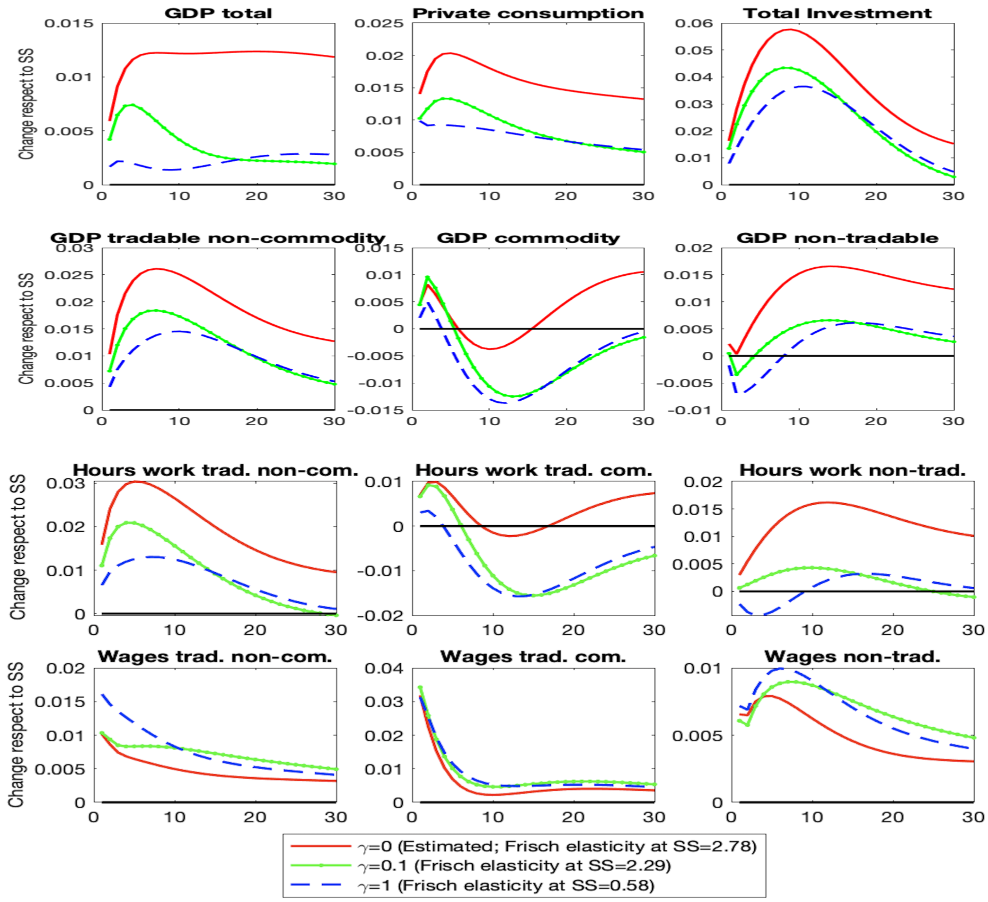
Figure 13: Response of SOE model to commodity price shocks for different price elasticities of demand for non-commodity exports



Note: The graph shows impulse response functions from the estimated SOE model, evaluated for different values of the price elasticity of demand for non-commodity exports.

The large income effect on worked hours decreases the Frisch elasticity of labor supply, making labor supply more inelastic and total hours worked less responsive to changes in real wages. This mitigates the expansion of total GDP, consumption, and investment produced by positive commodity price shocks.

Figure 14: Response of SOE model to commodity price shocks for different values of the income effect parameter for labor supply



Note: The figure depicts impulse response functions from the estimated SOE model, evaluated for different values of the sensitivity of labor supply to the income effect. I compute the Frisch elasticity of labor supply using the First Order Condition for labor supply log-linearized around the steady state. See Holden et. al. 2018.

VI Trade policy counterfactual

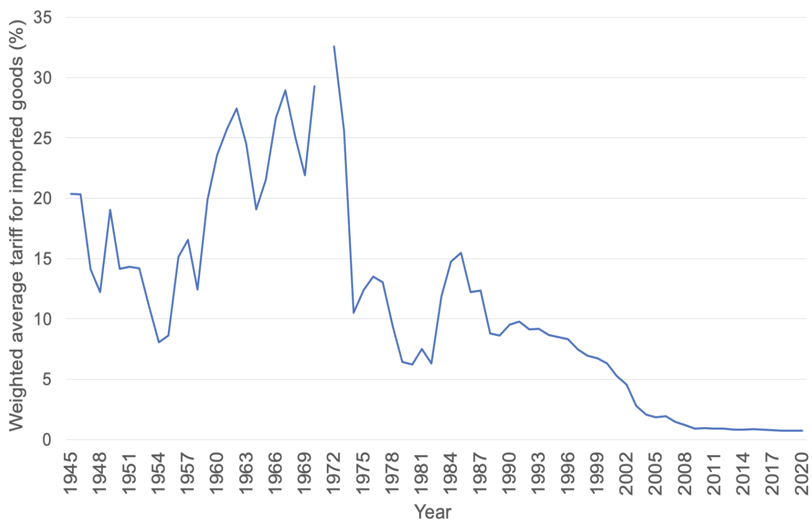
Chile has swung from protectionism to a free trade policy in the last 60 years. Figure 15 illustrates the weighted average tariff for Chilean imports was around 30% at the beginning of the 70s.[34] Since then, the weighted average tariff has been falling, reaching close to a zero tariff during the decade 2010s, because of free trade agreements between Chile and its trade partners.

Tariffs on imports are a relevant policy to evaluate because affect the substitutability between

[34]Between the 50s and the 70s, Chile implemented the Import Substitution Industrialization policy characterized by high tariffs and large import barriers in order to protect manufacturing.

domestic and imported goods and the demands for these products, then shaping the effect of commodity price shocks, as we see in the previous section.

Figure 15: Weighted average tariff for Chilean imports 1945-2020



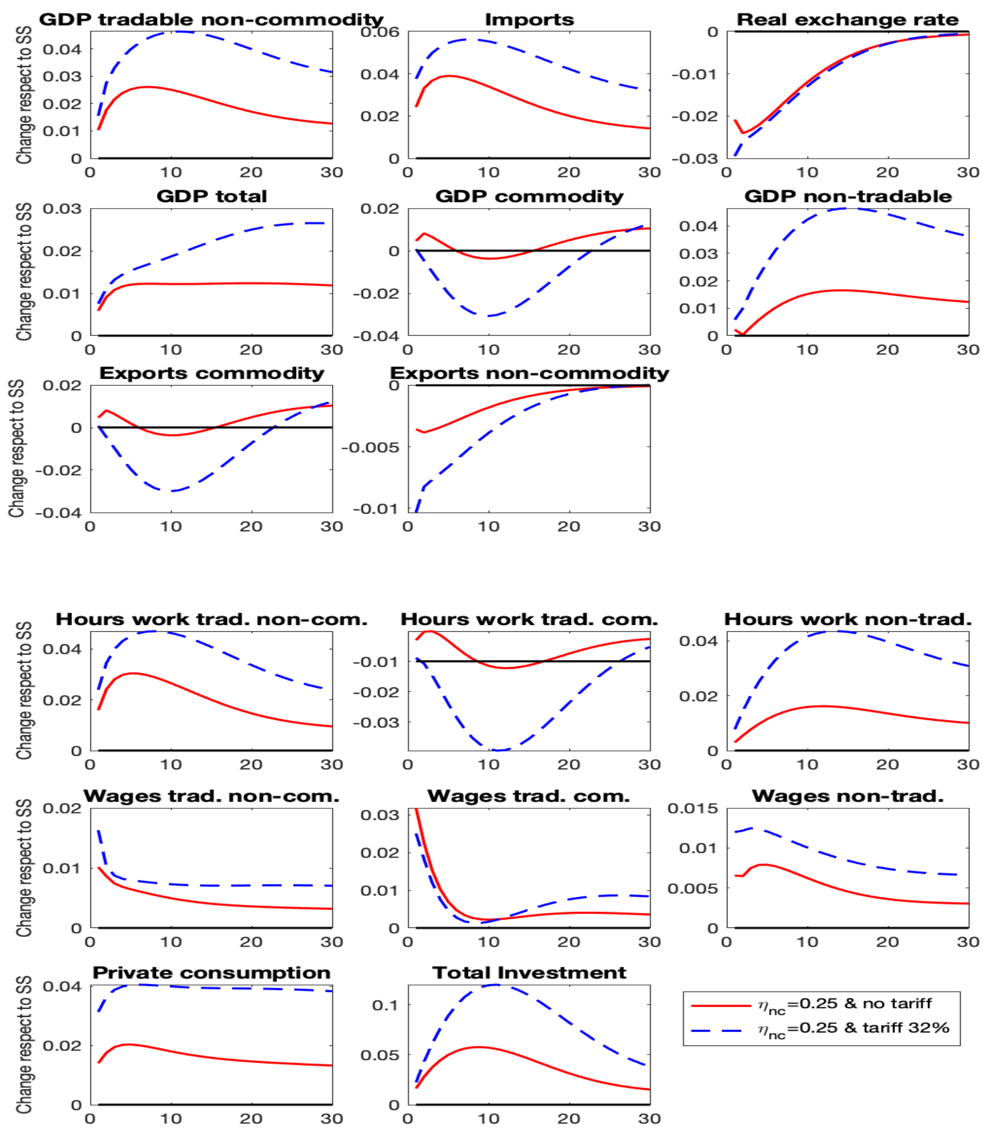
Note: The weighted average is the ratio of the total amount of tariffs and duties collected by the Chilean customs services and the total CIF value of imported goods.
Sources: Braun et al. (2000), Direction of budgets of Chile, and National Customs Service of Chile.

Figure 16 compares how tariffs equivalent to the maximum historical weighted average (32% in 1972) shape the effect of a commodity price shock with respect to the zero tariffs policy. The Small Open Economy is more sensitive to commodity price shock when a protectionist policy with high tariffs is implemented because tariffs make the predominant income effect on goods even larger.

High tariffs make domestic goods relatively cheaper than imports, increasing the domestic demand for tradable non-commodity goods. The rise in demand is partially covered by an increase in production and hours worked, while the rest of this bigger demand is covered by a crowding out in exports, also related to increases in domestic goods prices, making domestic products more expensive in foreign markets. A bigger production of domestic tradable non-commodity goods expands income and demand for goods through a predominant income effect on goods, which overcomes the substitution effect on imports associated with more expensive foreign goods with high tariffs, increasing imports.

The large income effects on goods generate an increase in consumption and investment, which generates a large expansion of non-tradable output and hours worked too. Given the large increases in real wages in tradable non-commodity, and non-tradable sectors, households reallocate hours worked from the commodity sector to other sectors, producing a contraction of output and exports from the commodity sector.

Figure 16: Impulse response functions to commodity price shocks for different values of import tariffs



Note: The figure illustrates impulse response functions from the estimated SOE model, evaluated for different values of tariffs on imported goods.

This result depends on the elasticity of substitution between domestic goods and imports. If the elasticity of substitution is large, the protectionist policy would mitigate the effect of commodity price shocks on imports and GDP total during the first 3 years. However, the effect on the GDP total is more persistent and even larger after 3 years, as Figure 31 from Appendix VII indicates.

Conclusions

This paper estimates the effects of copper price changes coming from copper-specific demand shocks on the overall Chilean economy and across sectors. I find an increase in real copper price generates a predominant income effect on goods that expand GDP in most of the economic sectors.

Despite the appreciation of the real exchange rate coming from copper price increases, sectoral exports do not fall, and manufacturing sectors related to copper activity expand while other manufacturing sectors do not change significantly. This is evidence against the Dutch disease about a contraction of manufacturing output and exports coming from commodity price increases.

The analysis of the estimated small open economy model indicates commodity price shocks produce the Dutch disease when the elasticity of substitution between domestic goods and imports or the price elasticity of demand for non-commodity exports are high because large elasticities make the demand for domestic goods highly sensitive to changes in the real exchange rate related to commodity price variations.

A relatively large reaction of hours worked and output is associated with low income effect on labor supply, which affects the Frisch elasticity of labor supply, making hours worked highly sensitive to an increase in labor demand and real wages associated with the expansionary effect of commodity price increases.

When the elasticity of substitution between domestic goods and imports is small, high tariffs on imports make the effect of commodity price shocks on the small open economy large because makes domestic goods cheaper, enlarging the demand for domestic products. Then, the large rise in domestic production produces predominant income effects on goods that expand the overall small open economy.

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Appendix I: Copper market industry

Table 3: Production of refined copper in the World

	1992-1995		1996-2000		2001-2005		2006-2010		2011-2015		2016-2020	
	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total
China	802.0	7.1%	1,211.0	8.7%	1958.2	12.4%	3796.1	20.7%	6664.4	31.4%	9148.7	38.8%
Chile	1,319.9	11.6%	2,306.9	16.5%	2859.0	18.2%	3065.2	16.7%	2833.4	13.3%	2420.3	10.3%
Japan	1,164.2	10.2%	1,317.3	9.4%	1406.5	8.9%	1527.4	8.3%	1470.0	6.9%	1542.8	6.5%
Russia	567.5	5.0%	691.1	5.0%	896.1	5.7%	906.7	4.9%	889.6	4.2%	978.4	4.2%
USA	2,224.6	19.6%	2,246.0	16.1%	1438.4	9.1%	1223.2	6.7%	1061.6	5.0%	1071.8	4.5%
Dem. Republic Congo					10.6	0.1%	88.7	0.5%	596.1	2.8%	783.9	3.3%
Germany	605.5	5.3%	689.1	4.9%	655.6	4.2%	679.1	3.7%	681.8	3.2%	658.6	2.8%
South Korea	221.1	1.9%	360.2	2.6%	501.6	3.2%	555.5	3.0%	597.2	2.8%	642.4	2.7%
Poland	400.5	3.5%	453.7	3.3%	529.4	3.4%	533.2	2.9%	570.7	2.7%	537.3	2.3%
Kazakhstan	294.9	2.6%	329.9	2.4%	434.2	2.8%	385.1	2.1%	351.1	1.7%	448.9	1.9%
Total	11,367.9		13,959.3		15733.7		18346.8		21228.3		23555.4	

Note: The table shows refined copper production in thousands of metric tons.

Source: Cochilco.

Table 4: Consumption of refined copper in the World

	1992-1995		1996-2000		2001-2005		2006-2010		2011-2015		2016-2020	
	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total
China	951.9	8.3%	1455.4	10.7%	3002.1	19.2%	5619.5	31.0%	9852.5	46.2%	12648.4	53.0%
USA	2436.9	21.4%	2843.8	20.9%	2391.3	15.3%	1923.2	10.6%	1778.4	8.3%	1786.2	7.5%
Germany	1003.8	8.8%	1118.9	8.2%	1083.5	6.9%	1328.4	7.3%	1172.2	5.5%	1140.0	4.8%
Japan	1396.2	12.2%	1363.5	10.0%	1203.7	7.7%	1130.9	6.2%	1010.9	4.7%	982.2	4.1%
South Korea	442.3	3.9%	685.0	5.0%	898.7	5.7%	858.1	4.7%	738.2	3.5%	699.0	2.9%
Italy	492.5	4.3%	584.7	4.3%	685.6	4.4%	668.1	3.7%	593.5	2.8%	561.7	2.4%
Turkey	118.3	1.0%	201.0	1.5%	251.1	1.6%	349.9	1.9%	437.4	2.1%	458.8	1.9%
India	115.5	1.0%	200.6	1.5%	320.4	2.0%	500.8	2.8%	441.4	2.1%	491.1	2.1%
Mexico	170.3	1.5%	328.8	2.4%	422.9	2.7%	321.9	1.8%	347.9	1.6%	407.6	1.7%
Taiwan	500.8	4.4%	599.8	4.4%	628.6	4.0%	570.8	3.1%	452.6	2.1%	427.3	1.8%
Total	11402.2		13589.3		15631.9		18151.0		21308.6		23858.2	

Note: The table indicates refined copper consumption in thousands of metric tons.

Source: Cochilco.

Table 5: Exports of refined copper in the World

	1992-1995		1996-2000		2001-2005		2006-2010		2011-2015		2016-2020	
	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total
Chile	1240.7	28.4%	2197.3	35.4%	2766.2	38.5%	2967.6	37.5%	2682.6	31.8%	2349.7	27.8%
Japan	133.3	3.0%	246.6	4.0%	305.2	4.2%	465.3	5.9%	520.4	6.2%	606.6	7.2%
Russia	305.6	7.0%	568.1	9.1%	442.5	6.2%	330.5	4.2%	321.5	3.8%	623.2	7.4%
Kazakhstan	139.9	3.2%	323.5	5.2%	391.5	5.4%	325.9	4.1%	328.9	3.9%	420.7	5.0%
Australia	156.6	3.6%	187.5	3.0%	344.4	4.8%	313.8	4.0%	417.0	4.9%	393.4	4.7%
Poland	242.8	5.6%	210.4	3.4%	268.8	3.7%	283.7	3.6%	322.2	3.8%	259.2	3.1%
Peru	225.6	5.2%	364.3	5.9%	427.6	6.0%	399.4	5.0%	292.4	3.5%	282.2	3.3%
Philippines	122.6	2.8%	117.9	1.9%	148.0	2.1%	156.6	2.0%	80.6	1.0%	175.2	2.1%
Zambia	375.3	8.6%	246.1	4.0%	365.3	5.1%	596.6	7.5%	807.8	9.6%	328.3	3.9%
Total	4370.5		6209.5		7185.9		7909.6		8435.7		8443.8	

Note: The table shows refined copper exports in thousands of metric tons.

Source: Cochilco.

Table 6: Imports of refined copper in the World

	1992-1995		1996-2000		2001-2005		2006-2010		2011-2015		2016-2020	
	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total
China	172.3	3.6%	294.6	4.9%	1159.1	17.0%	1977.2	26.9%	3342.3	39.7%	3769.1	41.2%
USA	383.6	8.1%	785.9	13.1%	925.7	13.6%	771.3	10.5%	656.8	7.8%	722.0	7.9%
Germany	516.0	10.9%	562.2	9.3%	542.7	7.9%	795.4	10.8%	694.8	8.3%	641.8	7.0%
Italy	409.7	8.6%	536.2	8.9%	659.2	9.7%	662.0	9.0%	600.3	7.1%	568.8	6.2%
Taiwan	503.4	10.6%	601.0	10.0%	630.1	9.2%	576.1	7.8%	453.8	5.4%	505.4	5.5%
Thailand	132.2	2.8%	131.8	2.2%	203.1	3.0%	247.4	3.4%	250.3	3.0%	363.5	4.0%
Turkey	23.4	0.5%	113.6	1.9%	198.9	2.9%	269.7	3.7%	359.8	4.3%	366.7	4.0%
South Korea	382.7	8.1%	427.5	7.1%	436.7	6.4%	421.7	5.7%	335.2	4.0%	297.8	3.3%
Brazil	76.8	1.6%	126.4	2.1%	143.4	2.1%	221.5	3.0%	220.7	2.6%	183.2	2.0%
France	459.7	9.7%	541.1	9.0%	565.3	8.3%	373.2	5.1%	217.8	2.6%	213.6	2.3%
Total	4748.1		6016.9		6828.0		7338.8		8411.6		9139.5	

Note: The table shows refined copper imports in thousands of metric tons.

Source: Cochilco.

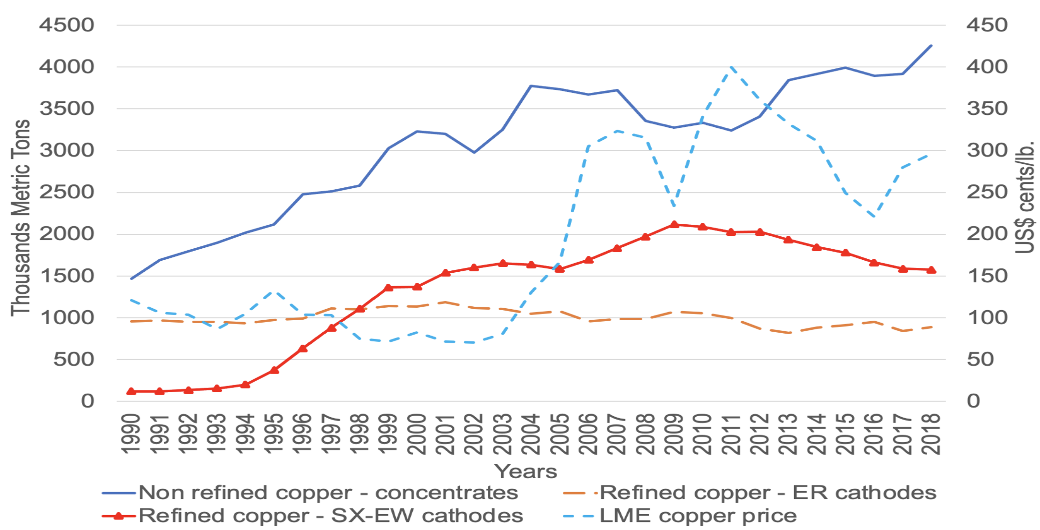
Table 7: Production of copper by company in Chile

	1992-1995		1996-2000		2001-2005		2006-2010		2011-2015		2016-2020	
	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total	Annual avg.	% total
Codelco	1,148.6	55.5%	1,375.7	35.8%	1,734.7	34.8%	1,707.6	31.6%	1,815.5	32.4%	1,781.9	31.4%
Mantos Copper (Audley Capital Advisors)	74.5	3.6%	140.1	3.6%	152.4	3.1%	148.8	2.7%	113.5	2.0%	87.1	1.5%
Anglo American Sur	174.9	8.5%	224.2	5.8%	274.7	5.5%	283.0	5.2%	404.5	7.2%	377.0	6.6%
Escondida (BHP Billiton)	418.9	20.2%	903.4	23.5%	1,002.7	20.1%	1,236.8	22.9%	1,081.0	19.3%	1,109.0	19.5%
Candelaria (Freeport McMoran)	90.6	4.4%	187.7	4.9%	199.0	4.0%	158.9	2.9%	144.8	2.6%	118.7	2.1%
Collahuasi (Xstrata Plc)			306.2	8.0%	437.8	8.8%	479.3	8.9%	421.1	7.5%	556.8	9.8%
Los Pelambres (Antofagasta Plc)			160.6	4.2%	348.7	7.0%	341.4	6.3%	408.7	7.3%	368.5	6.5%
Other companies	161.9	7.8%	1,006.6	26.2%	1,627.8	16.9%	1,876.7	19.5%	2,041.8	21.6%	2,208.0	22.6%
Total	2,069.3		3,837.6		4,991.4		5,411.7		5,601.2		5,681.6	

Note: The table shows refined copper production in thousands of metric tons.

Source: Cochilco.

Figure 22: Copper and refined copper production by type in Chile

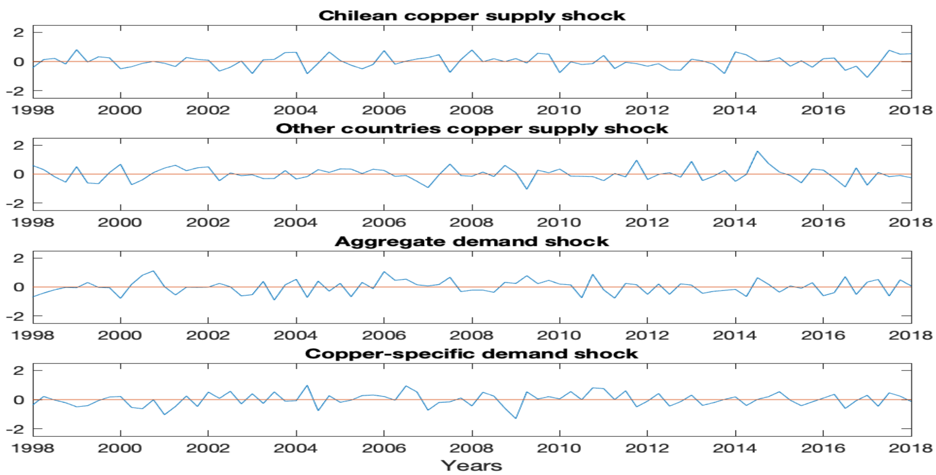


Note: The figure shows the total production of copper and refined copper in thousands of metric tons in Chile. It also indicates the annual average reference price of refined copper grade A traded in the London Metal Exchange (LME) market.

Source: Chilean Commission of Copper (Cochilco)

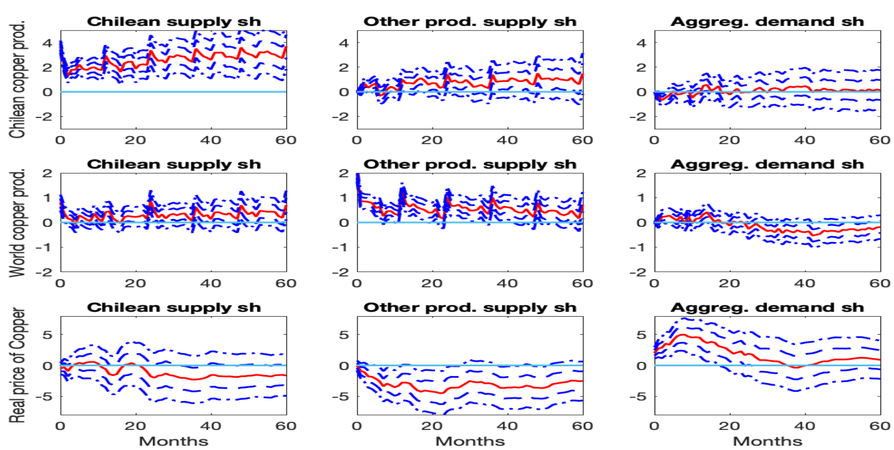
Appendix II: World copper market shocks

Figure 23: Historical evolution of the structural shocks 1998-2018



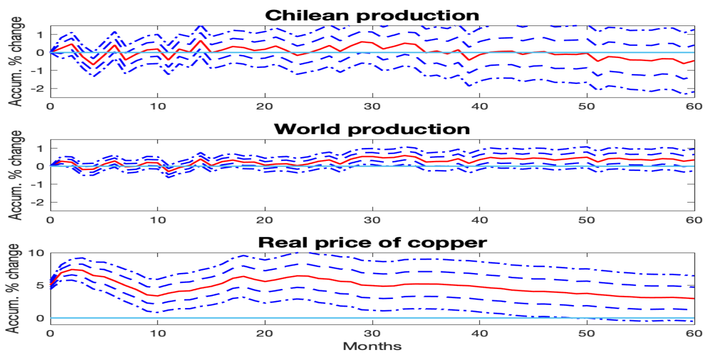
Note: The figure indicates the quarterly average of the structural shocks recovered from the SVAR model of the world copper market.

Figure 24: Response of real copper price and refined copper production to demand and supply shocks



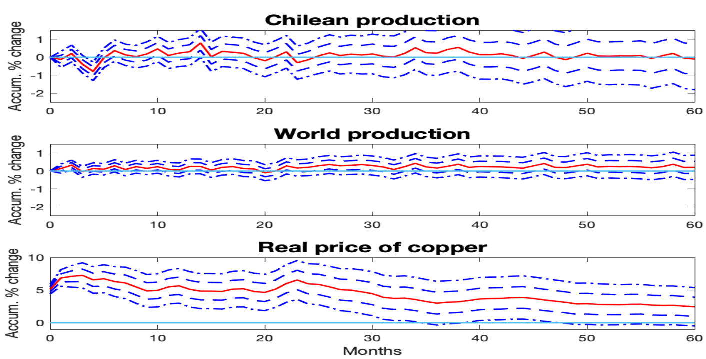
Note: The figure illustrates the impulse response functions of accumulated percentage change of monthly refined copper production and real price of copper to one standard deviation structural shocks from the SVAR model. Dashed and dotted lines represent the confidence bands of one and two standard deviations respectively. The confidence intervals were computed using a recursive design wild bootstrap with 2000 replications (Goncalves and Kilian, 2004).

Figure 25: Response of real copper price, and World and Chilean copper production to a copper specific demand shock



Note: The figure illustrates the impulse response functions of accumulated percentage change of monthly total copper production (refined and non-refined) production and real price of copper to one standard deviation copper-specific demand shocks from the SVAR model. Dashed and dotted lines represent the confidence bands of one and two standard deviations respectively. The confidence intervals were computed using a recursive design wild bootstrap with 2000 replications (Goncalves and Kilian, 2004).

Figure 26: Response of real copper price and refined copper production to a copper specific demand shock using industrial production for OECD and 6 main economies as global economic activity index



Note: The figure illustrates the impulse response functions of accumulated percentage change of monthly refined copper production and real price of copper to one standard deviation copper-specific demand shocks from the SVAR model. Dashed and dotted lines represent the confidence bands of one and two standard deviations respectively. The confidence intervals were computed using a recursive design wild bootstrap with 2000 replications (Goncalves and Kilian, 2004). For more information about industrial production index, see Baumeister and Hamilton (2019).

Appendix III: Productive relation Copper sector with other sectors in Chile

Table 8: Sectoral representation in the real GDP and upstream and downstream relation with the copper sector in 1996

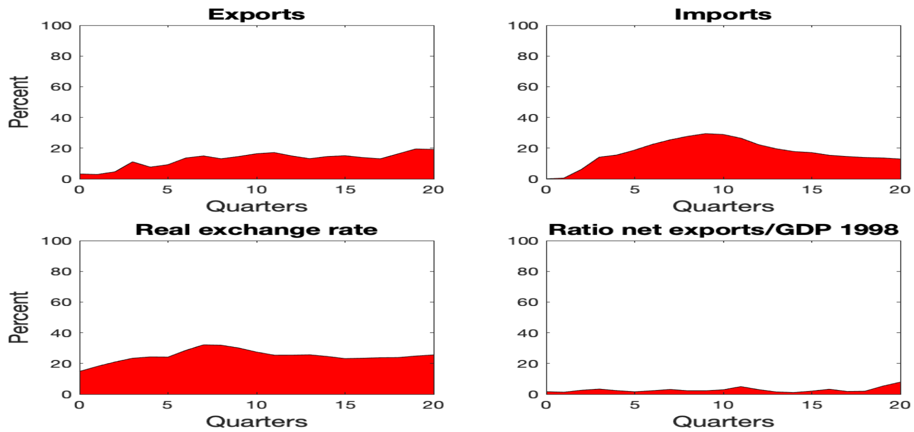
	Ratio sectoral and total GDP in 1996	% Total Selling to Copper sector in 1996 (Upstream rel.)	Copper inputs as % total product value in 1996 (Downstream rel.)
Total		2.18%	0.76%
Agriculture and Forestry	3.0%	0.01%	0.00%
Fishery	0.5%	0.00%	0.00%
Manufacturing	14.9%	1.28%	0.41%
Food manufacturing	6.0%	0.02%	0.00%
Clothing manufacturing	0.4%	0.17%	0.00%
Wood product manufacturing	1.3%	0.09%	0.00%
Paper manufacturing	1.1%	0.27%	0.00%
Chemicals and Petroleum products	2.9%	2.37%	0.08%
Primary metal manufacturing	0.9%	6.81%	12.20%
Fabricated metal and Machinery	2.2%	4.04%	0.02%
Mines	15.1%	10.47%	8.94%
Copper Mines	12.7%	11.79%	10.97%
Other Mines	1.9%	5.70%	0.00%
Services	54.9%	2.02%	0.00%
Utilities	3.4%	10.48%	0.00%
Construction	8.2%	0.25%	0.00%
Retail trade	8.7%	0.80%	0.00%
Transportation	3.9%	2.00%	0.00%
Communication	1.3%	0.15%	0.00%
Financial and Professional services	7.9%	0.63%	0.00%
Other services	8.5%	3.18%	0.00%
Education and Health Care	13.0%	0.10%	0.00%

Table 9: Sectoral representation in the real GDP and upstream and downstream relation with the copper sector in 2013

	Ratio sectoral and total GDP in 2013	% Total Selling to Copper sector in 2013 (Upstream rel.)	Copper inputs as % total product value in 2013 (Downstream rel.)
Total		2.47%	0.84%
Agriculture and Forestry	2.9%	0.00%	0.00%
Fishery	0.5%	0.00%	0.00%
Manufacturing	11.1%	1.00%	0.69%
Food manufacturing	4.4%	0.00%	0.00%
Clothing manufacturing	0.3%	0.09%	0.00%
Wood product manufacturing	0.6%	0.00%	0.00%
Paper manufacturing	0.9%	0.00%	0.00%
Chemicals and Petroleum products	2.4%	2.49%	0.07%
Primary metal manufacturing	0.7%	0.00%	17.84%
Fabricated metal and Machinery	1.9%	0.94%	0.17%
Mines	11.0%	5.79%	6.76%
Copper Mines	9.8%	7.94%	7.59%
Other Mines	1.2%	0.00%	0.52%
Services	0.0%	3.09%	0.00%
Utilities	2.6%	14.70%	0.00%
Construction	6.5%	0.02%	0.00%
Retail trade	10.9%	0.55%	0.00%
Transportation	4.7%	2.98%	0.00%
Communication	3.1%	1.44%	0.00%
Financial and Professional services	15.7%	0.73%	0.00%
Other services	7.1%	4.64%	0.00%
Education and Health Care	10.9%	0.00%	0.00%

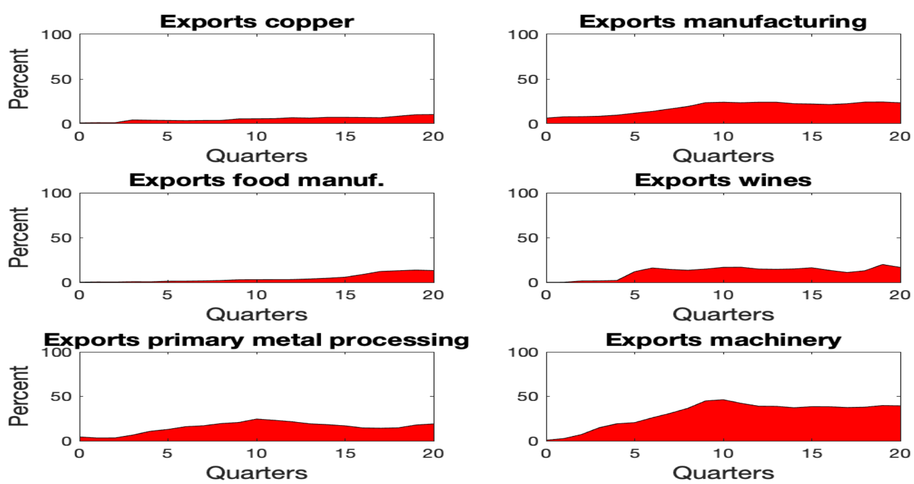
Appendix IV: Variance decomposition with local projections

Figure 27: Forecast error variance decomposition for external variables with local projections



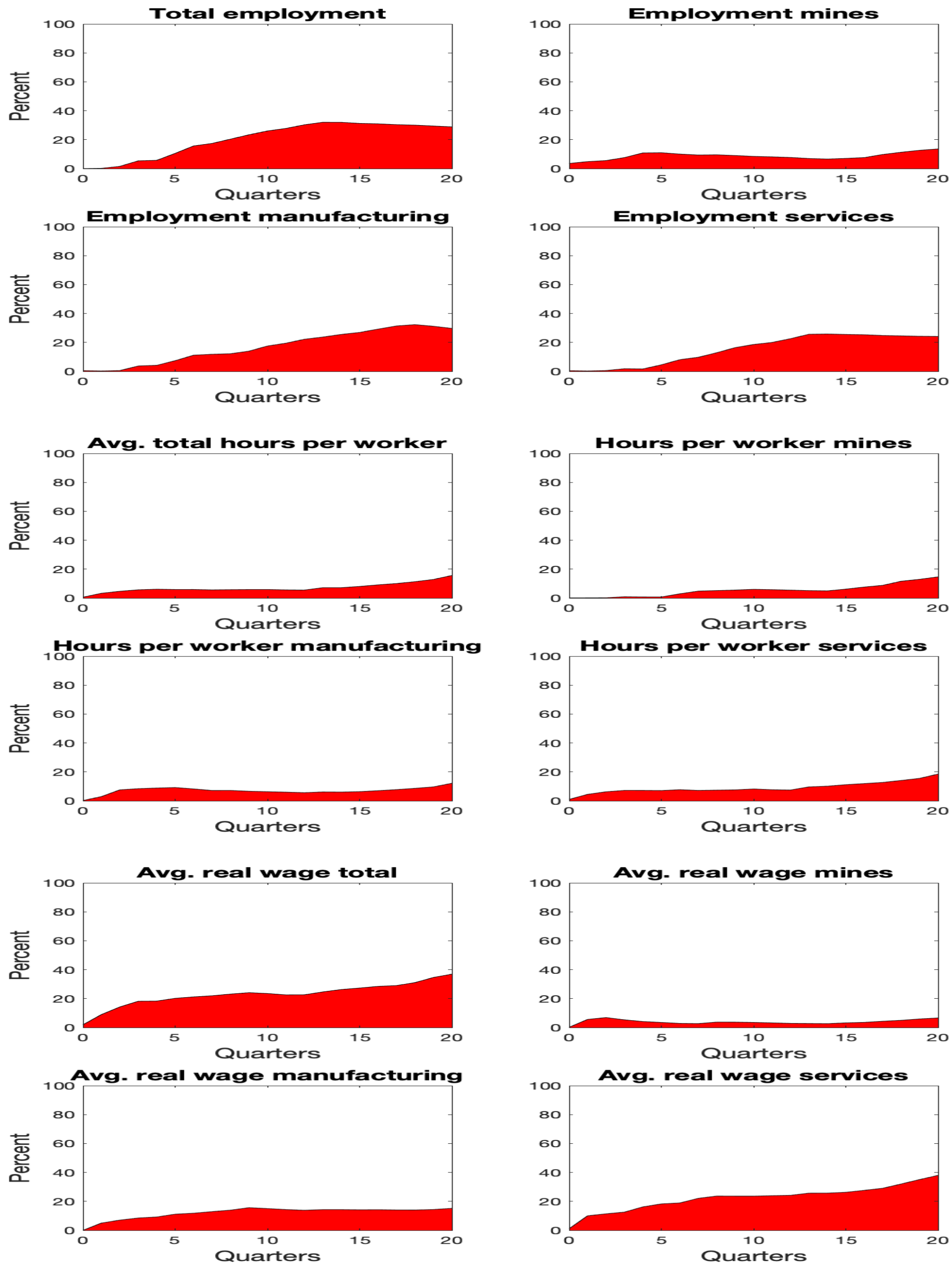
Note: The red area represents the percentage of forecast error explained by copper-specific demand shocks across quarters, using the method proposed by Gorodnichenko and Lee (2020). Plagborg-Moller and Wolf (2022) provided conditions for forecast error variance decomposition using instrumental variables methods.

Figure 28: Forecast error variance decomposition for sectoral exports with local projections



Note: The red area represents the percentage of forecast error explained by copper-specific demand shocks across quarters, using the method proposed by Gorodnichenko and Lee (2020). Plagborg-Moller and Wolf (2022) provided conditions for forecast error variance decomposition using instrumental variables methods.

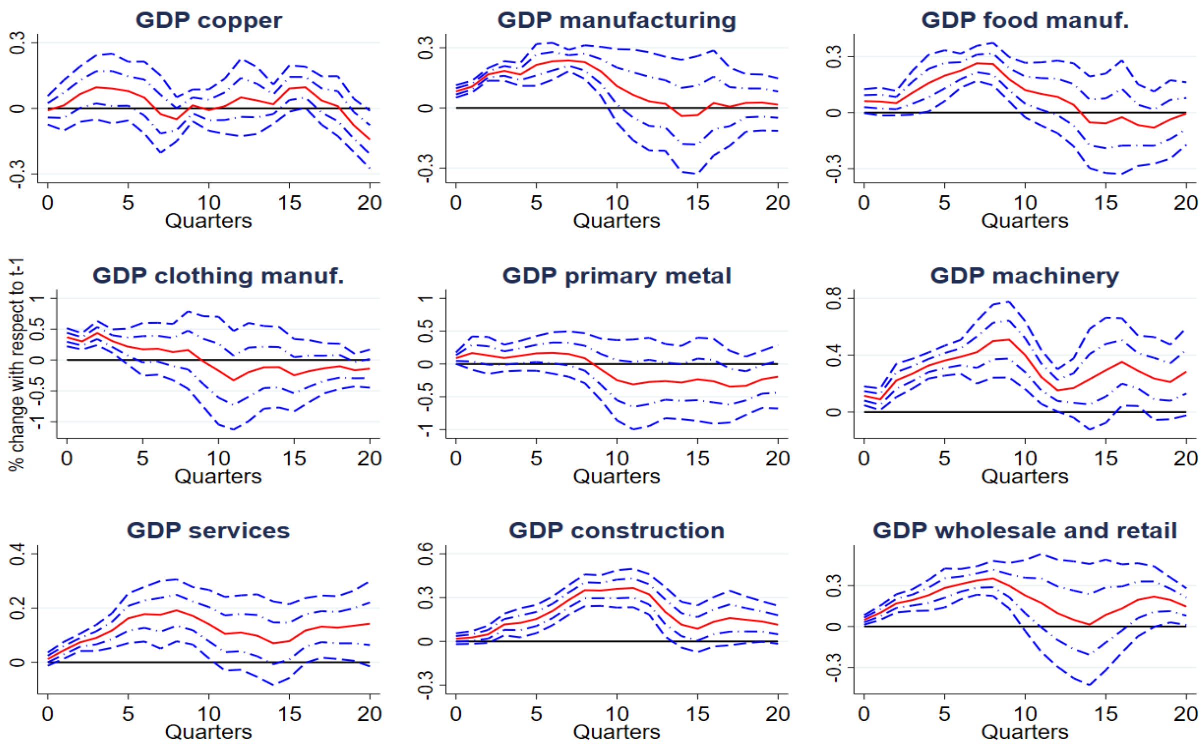
Figure 29: Forecast error variance decomposition for labor market outcomes with local projections



Note: The red area represents the percentage of forecast error explained by copper-specific demand shocks across quarters, using the method proposed by Gorodnichenko and Lee (2020). Plagborg-Moller and Wolf (2022) provided conditions for forecast error variance decomposition using instrumental variables methods.

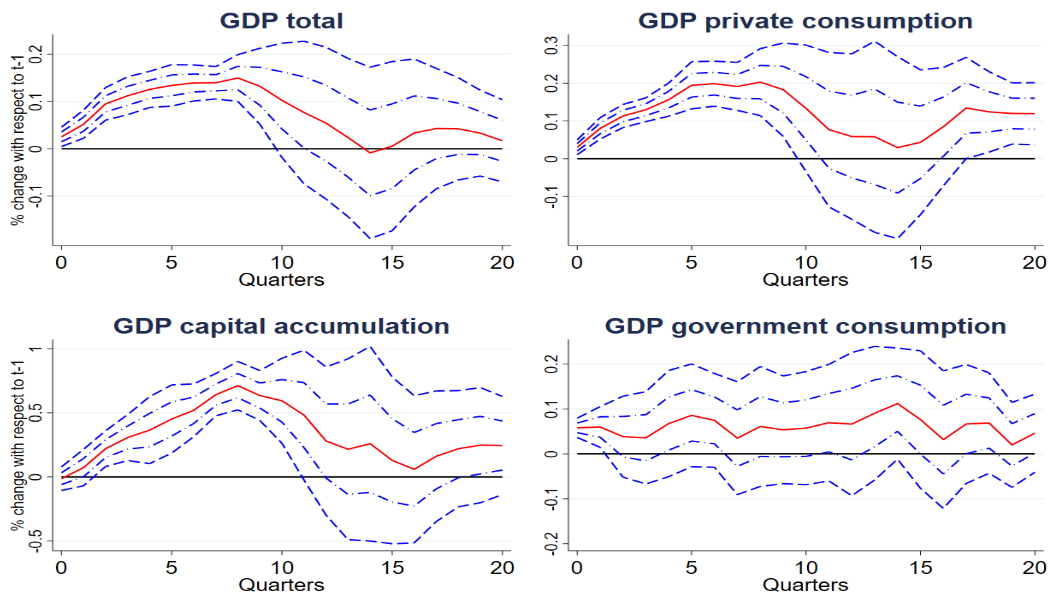
Appendix V: Robustness check with estimation with data since 2000

Figure 30: Response of sectoral GDP to copper prices changes coming from copper-specific demand shocks



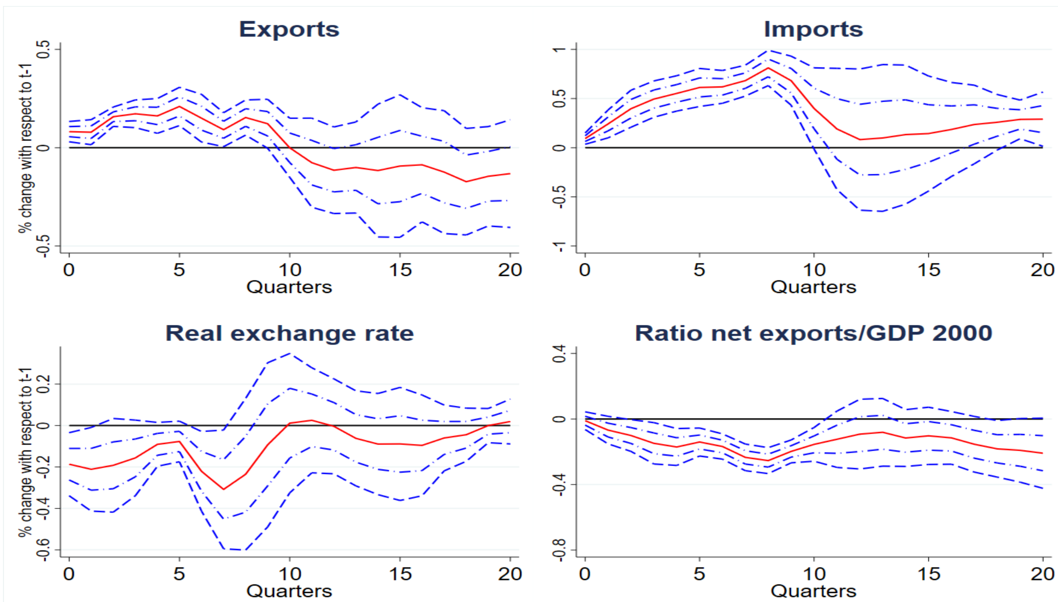
Note: The figure shows the impulse response functions (IRF) of accumulated percentage changes of real GDP to a percentage change of real copper price coming from copper-specific demand shocks. I estimate these IRFs with an IV local projection model, in which the F statistic of the First stage regression is 22.27 and the robust F statistic is 27.08 (see Montiel-Olea and Pflueger, 2013), significant at 5%. The dashed and dotted lines represent the confidence bands to one and two standard deviations respectively, which are heteroskedastic and autocorrelation consistent (HAC) robust.

Figure 31: Response of aggregate GDP to copper prices changes coming from copper-specific demand shocks



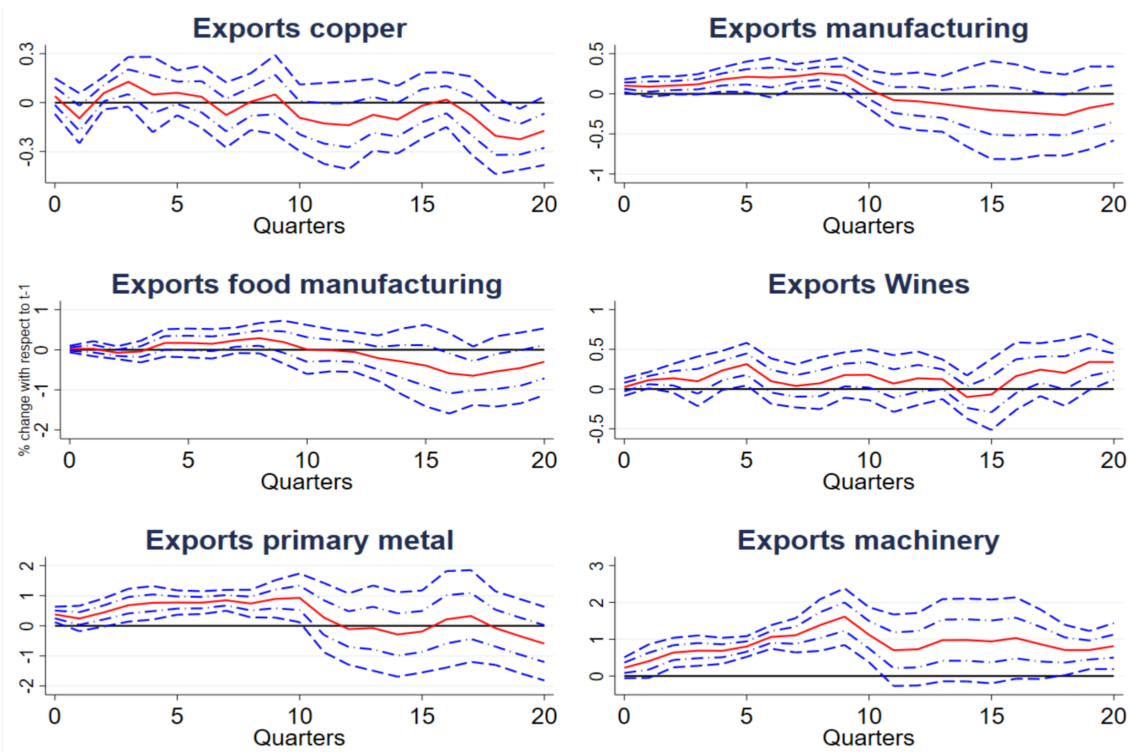
Note: The figure shows the impulse response functions (IRF) of accumulated percentage changes of real GDP to a percentage change of real copper price coming from copper-specific demand shocks. I estimate these IRFs with an IV local projection model, in which the F statistic of the First stage regression is 29.44 and the robust F statistic is 22.46 (see Montiel-Olea and Pflueger, 2013), significant at 5%. The dashed and dotted lines represent the confidence bands to one and two standard deviations respectively, which are heteroskedastic and autocorrelation consistent (HAC) robust.

Figure 32: Response of exports, imports and real exchange rate to copper prices changes coming from copper-specific demand shocks



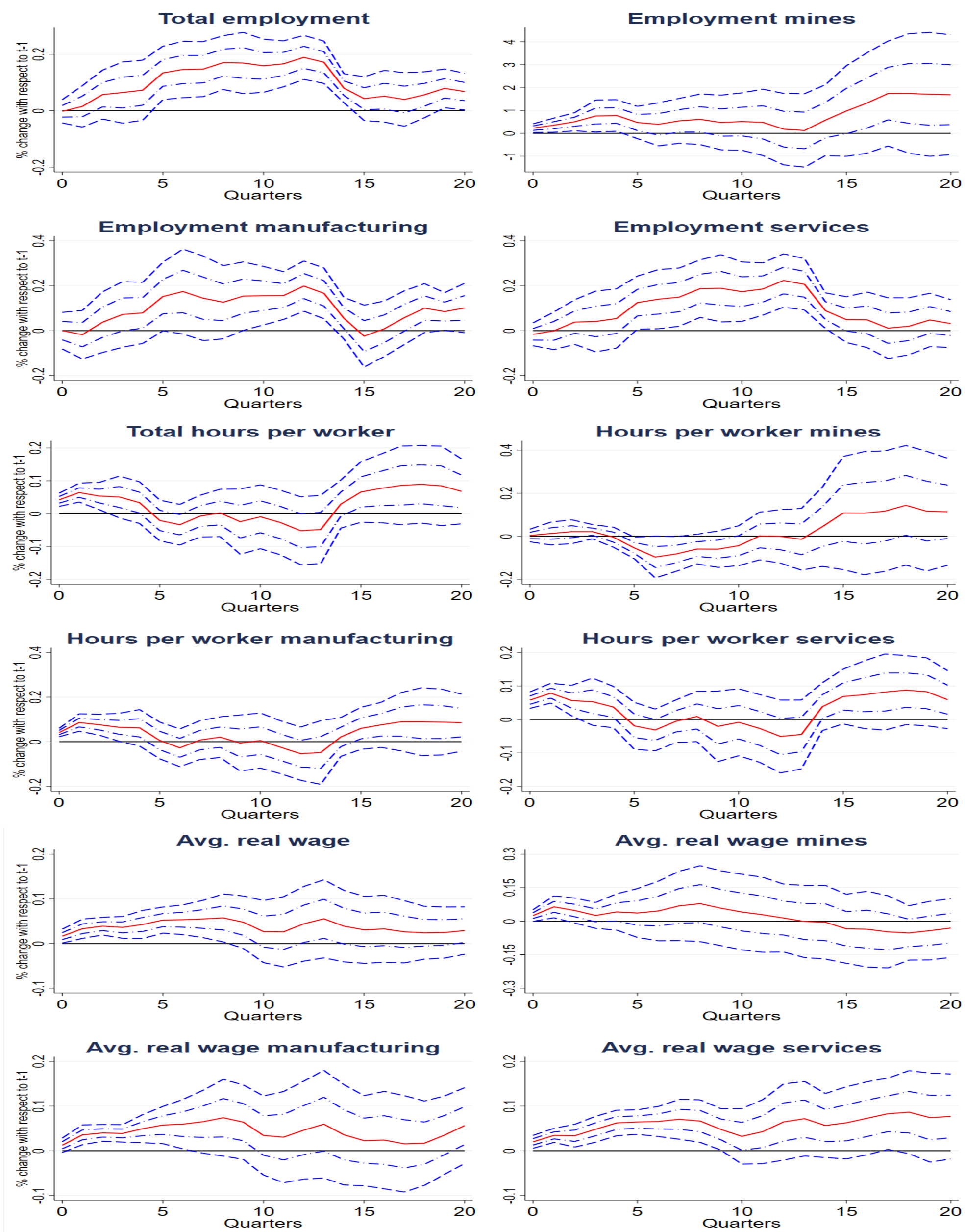
Note: The figure indicates the impulse response functions (IRF) of accumulated percentage changes of real exchange rate, and real values of total exports, imports, and net exports to a percentage change of real copper price coming from copper-specific demand shocks. I estimate these IRFs with an IV local projection model, in which the F statistic of the First stage regression is 28.56, and the robust F statistic is 26.48 (see Montiel-Olea and Pflueger, 2013), significant at 5%. The dashed and dotted lines represent the confidence bands to one and two standard deviations respectively, which they are heteroskedastic and autocorrelation consistent (HAC) robust.

Figure 33: Response of sectoral exports to copper prices changes coming from copper-specific demand shocks



Note: The figure shows the impulse response functions (IRF) of accumulated percentage changes of real values of exports to a percentage change of real copper price coming from copper-specific demand shocks. I estimate these IRFs with an IV local projection model, in which the F statistic of the First stage regression is 30.77 and the robust F statistic is 26.63 (see Montiel-Olea and Pflueger, 2013), significant at 5%. The dashed and dotted lines represent the confidence bands to one and two standard deviations respectively, which are heteroskedastic and autocorrelation consistent (HAC) robust.

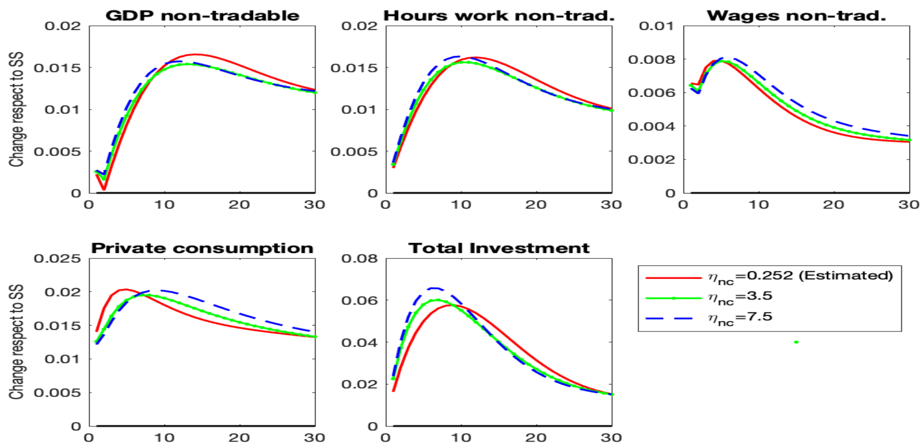
Figure 34: Response of labor market outcomes to copper prices changes coming from copper-specific demand shocks



Note: The figure reveals the impulse response functions (IRF) of accumulated percentage changes of the number of employed people, average hours per worker, and real average wages deflated by core CPI to a percentage change of real copper price coming from copper-specific demand shocks. I estimate these Impulse Response Functions with an IV local projection model, in which the F statistic of the first stage regression is 30.33, and the robust F statistic is 25.13 (see Montiel-Olea and Pflueger, 2013), significant at 5%. The dashed and dotted lines represent the confidence bands to one and two standard deviations respectively, which are heteroskedastic and autocorrelation consistent (HAC) robust.

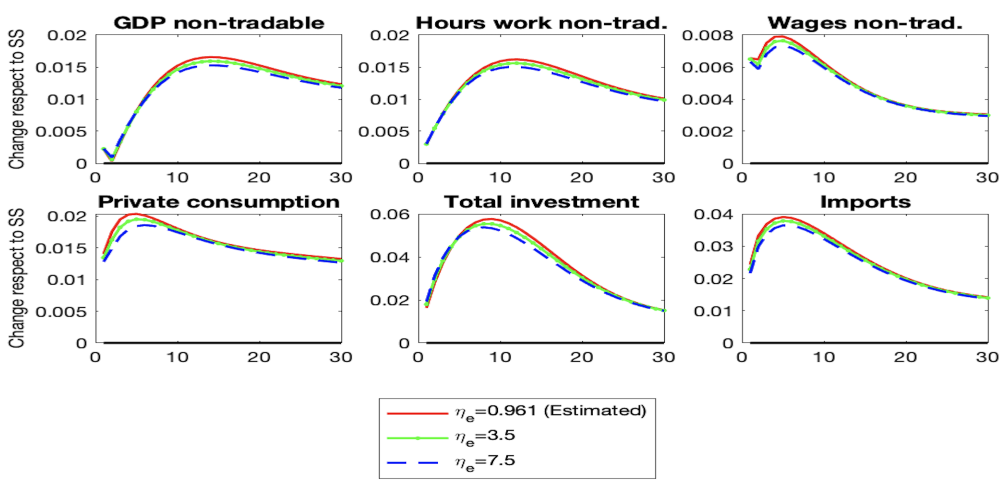
Appendix VI: Other outcomes of the counterfactual analysis

Figure 35: Response of SOE to commodity price shocks for different elasticities of substitution between domestic and imported goods



Note: The figure represents impulse response functions from the estimated SOE model, evaluated for different values of the elasticity of substitution between domestic tradable non-commodity and imported goods.

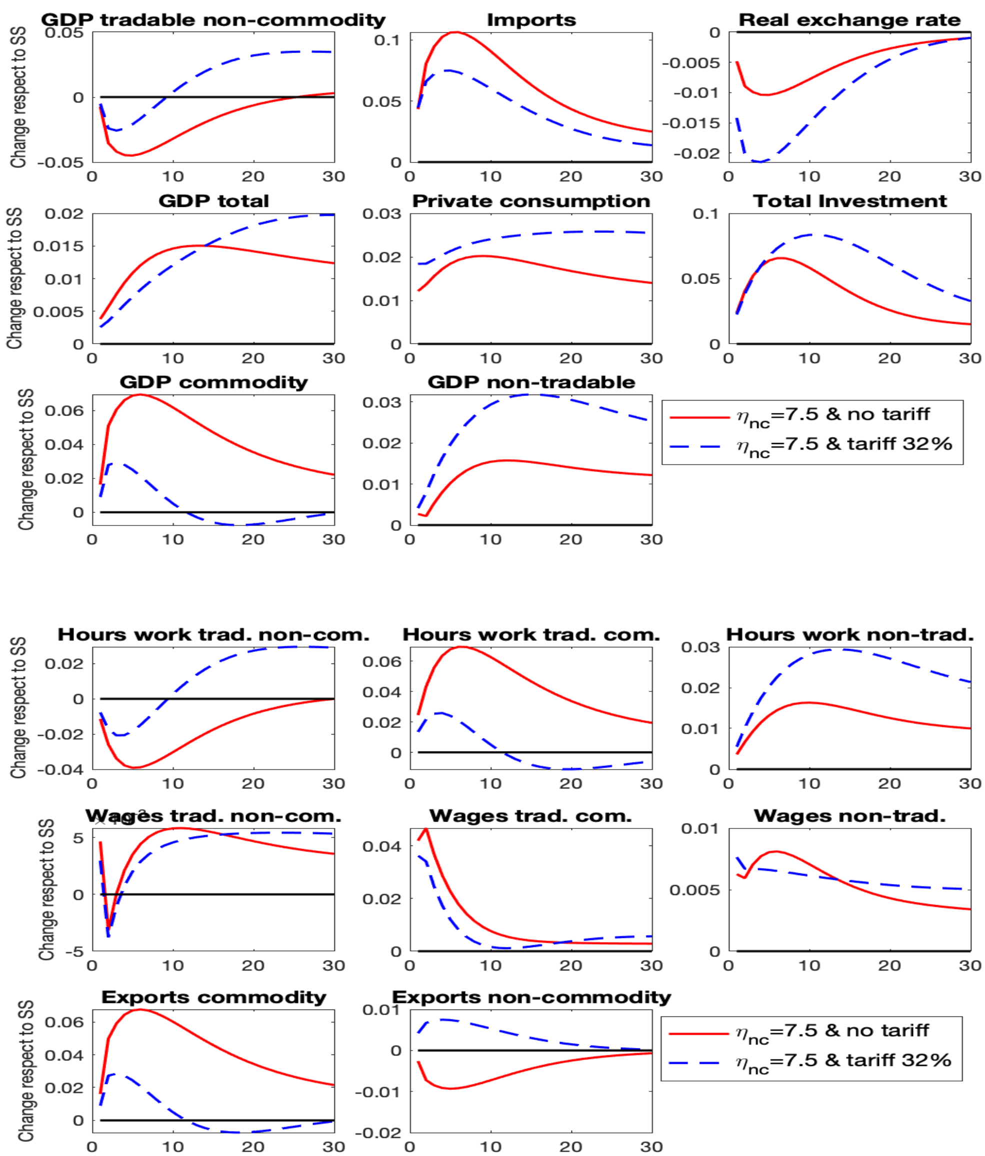
Figure 36: Response of SOE to commodity price shocks for different price elasticities of demand for exports



Note: The graph shows impulse response functions from the estimated SOE model, evaluated for different values of the price elasticity of domestic tradable non-commodity exports.

Appendix VII: Trade policy counterfactual with a high elasticity of substitution

Figure 37: Impulse response functions to commodity price shocks for different values of import tariffs, conditional on a large elasticity of substitution between domestic goods and imports



Note: The figure illustrates impulse response functions from the estimated SOE model, evaluated for different values of tariffs on imported goods.